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DEPARTMENT OF DEFENSE LAND FALLOUT PREDICTION SYSTEM

Volume III
CLOUD RISE
REVISED

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DASA-1800-III
(Revised)

ARCON

DEPARTMENT OF DEFENSE
LAND FALLOUT PREDICTION SYSTEM

Volume III - Cloud Rise
(Revised)

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ABSTRACT

The theoretical bases of a land-surface-burst nuclear-cloud-rise model and details of development from the theoretical model of the DELFIC Cloud Rise Module computer program are presented. By use of this dynamic cloud rise model, histories of the rise, growth, temperature, and composition of the cloud are computed throughout virtually the entire period of its rise. Effects on the cloud development of atmospheric structure can be accounted for, and the development of a time-temperature history for the cloud allows fractionation of the radioactive weapon debris to be approximately accounted for in the Particle Activity Module (DASA-1800-V) calculations.

Also described is the DELFIC Cloud Rise-Transport Interface Module (CRTIM). The CRTIM corrects particle positions for wind-drift during the cloud rise time period and prepares the particles aloft inputs for the DELFIC Transport Module (DASA-1800-IV).

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PART I

THEORETICAL BASIS OF A LAND SURFACE BURST CLOUD RISE MODEL

INTRODUCTION

The cloud rise model described here is a modified version of the water surface burst cloud rise model devised by Huebsch.[1.1,1.2,1.3] Modifications to the Huebsch model have been made to bring the simulations more in line with observed cloud rise behavior, particularly at times relatively early after the detonation. The studies that have led to these changes have been published by Norment and Woolf.[1.4,1.5] Since much of the model remains unrevised, we have taken many verbatum excerpts from Huebsch's work.[1.2,1.3]

Major changes in the model are as follows:

1. A completely new set of initial conditions is used.
2. The cloud momentum equation is revised.
3. The entrainment equation is revised.
4. There are no longer any discontinuities in the cloud behavior at the tropopause.
5. The cloud no longer is given a spherical shape. Initially the cloud is given an oblate spheroidal shape with eccentricity of 0.75. At all other times, the shape of the cloud is determined by the cloud volume and the vertical cloud radius which is taken to be a function of height of burst, explosion energy yield, and cloud center altitude.
6. The particle growth option has been deleted from the model.
7. Effects of wind shear on the cloud rise have been included.
8. The fraction of explosion energy in the cloud and eddy viscosity coefficient, k_2, both are taken to be yield dependent. Formerly they were constant.

The reader is referred to references 1.1 - 1.5 for details of derivations that are not covered here. Appendices B.1 and C.1 contain discussions of our modifications to the momentum and entrainment equations.

CLOUD RISE EQUATIONS

Cloud rise and expansion are described by a set of differential equations together with certain defining equations and initial and boundary conditions. For certain cases, the equations are given in pairs, that is, for "dry" and "wet" conditions. For the dry equations the cloud is unsaturated with respect to water; the "wet" equations are for the saturated cloud and include effects of water condensatio .

MOMENTUM

The momentum equation is obtained by equating the rate of change of momentum to the sum of buoyancy and eddy-viscous (drag) forces. After correcting for asymmetric entrainment (see Appendix B. 1), we obtain

$$\frac{du}{dt} = \left\{ \left[\frac{T^*}{T_e^*} \beta' - 1 \right] g/(1 - \mu) - \left[\frac{2k_2 v}{H_c} \frac{T^*}{T_e^*} \beta' (1 - \mu) + \frac{1}{m} \frac{dm}{dt} \right] u \right\} \frac{m}{m + m_i'} \tag{1.1}$$

where u is rate of cloud rise,

t is time

m is cloud mass

g is acceleration due to gravity

k_2 is a dimensionless power function of yield

$T^* = Tq(x)$

$T_e^* = T_e q(x_e)$

$\beta' = \dfrac{1 + x}{1 + x + s + w}$, the ratio of cloud gas density to total cloud density.

T and T_e are respectively cloud and ambient temperature

$q(x)$ the ratio of virtual to actual temperature, may be shown to equal

$$\frac{1 + x/\epsilon}{1 + x}$$

x and x_e are respectively cloud and ambient mixing ratios (ratios of water-vapor mass to dry air mass in a volume element)

ϵ = 18/29, tne ratio of the molecular weight of water vapor to that of (ry air

w is the ratio of condensed water mass to dry air mass in the cloud

s is the ratio of condensed dry mass to dry air mass in the cloud

T^* and T_e^* are thus the virtual temperatures, and $T^*\beta'$ is the (cloud) virtual temperature allowing fo: the contribution of condensed mass to the total cloud density.

v is a characteristic velocity given by $v = \max(|u|, \sqrt{2E})$ where E is turbulent energy density (see reference 1.1)

H_c is the vertica: radius of the cloud

m_i' is an initial virtual cloud mass equal to one half the initial displaced mass: $m_i' = m_i\beta' T_i^*/2T_{ei}^*$, where the subscript i indicates the initial value of each quantity.

μ is a dimensionless yield dependent quantity that is used to define the vertical cloud radius (equation (1.13)).

HEIGHT

The height, z, of the center of the cloud is given by

$$\frac{dz}{dt} = u \qquad (1.2)$$

WATER VAPOR

The mixing ratio, x, does not change by fallout of condensed matter but only by entrainment.

Dry

During the "dry" (unsaturated) period, no water is lost by condensation.

Let $\left.\frac{dm}{dt}\right|_{ent}$ be the mass-entrainment rate and $\left.dm\right|_{ent}$ the mass entrained in time dt. Then, at time t + dt, the new mixing ratio is

$$x(t + dt) = \frac{m\,\frac{x}{1 + x + s} + \left.dm\right|_{ent}\,\frac{x_e}{1 + x_e}}{\frac{m}{1 + x + s} + \frac{\left.dm\right|_{ent}}{1 + x_e}}$$

from which, by the definition of the derivative,

$$\frac{dx}{dt} = -\,\frac{1 + x + s}{1 + x_e}\,(x - x_e)\,\frac{1}{m}\,\left.\frac{dm}{dt}\right|_{ent} \qquad (1.3D)$$

<u>Wet</u>

For the saturated cloud, x is the saturation mixing ratio. Then, neglecting possible lowering of vapor pressure by particulate matter,

$$\frac{1}{x}\,\frac{dx}{dt} = (1 + x/\epsilon)\,\frac{L\epsilon}{R_a T^2}\,\frac{dT}{dt} + (1 + x/\epsilon)\,\frac{g}{R_a T_e^*}\,u \qquad (1.3W)$$

where R_a is the gas constant for dry air and L is the latent heat of evaporation of water or ice as appropriate.

TEMPERATURE

A temperature equation can be obtained from either (a) heat balance, as in Reference 1.1, or (b) enthalpy balance, since entrainment is a constant-pressure process. The second method is used here.

As before, dry and wet stages are considered separately. Although condensed matter is present during the dry stage, only the gas mass fraction, $(1 + x)/(1 + x + s)$, expands adiabatically as the cloud rises. The specific heat of entrained air is taken as that of dry air, c_{pa} (1).

The particulate (condensed) matter is assumed to be initially at some average temperature, $T_{rq} \leq T_i$, and to remain at this temperature until $T = T_{rq}$. Thereafter, thermal equilibrium with the cloud gas is assumed.

Dry

Let H be the total enthalpy of the cloud. We write enthalpy as the sum of gas and condensed-matter contributions:

$$H = m\beta' \int_0^T c_p(T)dT + m(1-\beta') \int_0^{\min(T, T_{rq})} c_s(T)dT$$

where $c_p(T)$ is the weighted mean of the specific heats at constant pressure of dry air and water vapor:

$$c_p(T) = \frac{c_{pa}(T) + xc_{pw}(T)}{1 + x}$$

and $c_s(T)$ is the specific heat of the condensed matter. The absolute-zero reference level is artificial and drops out in the derivation. Enthalpy is altered by entrainment, by fallout, by expansion, and by dissipation of turbulent energy at rate $\mathcal{E}$ per unit gas mass:

$$dH = dH_{ext} + Vdp + m\beta'\mathcal{E}\,dt \quad .$$

The enthalpy change due to mass change, dH_{ext}, consists of: (a) gain due to entrainment of gas at temperature T_e:

$$\int_0^{T_e} c_{pa}(T)dT \cdot dm\Big|_{ent}$$

and (b) loss due to fallout at temperature $\min(T, T_{rq})$:

$$\int_0^{\min(T, T_{rq})} c_s(T)\, dT\, p(t)\, dt$$

where p(t) is the total mass fallout rate. This rate, during the Dry stage, is negligibly small for water-surface bursts, but is significant for land-surface bursts. Using the gas law, we have

$$V = m\beta' \frac{R_a T^*}{P} \quad ,$$

where V is cloud volume. Taking the differential of H, and equating it to the sum of the enthalpy changes, gives:

$$m\left[\beta' c_p(T) + (1 - \beta') c_s(T) k(T, T_{rq})\right] dT + d(m\beta') \int_0^T c_{pa}(T)\, dT$$

$$+ \, d(m(1 - \beta')) \int_0^{\min(T, T_{rq})} c_s(T)\, dT$$

$$= \int_0^{T_e} c_{pa}(T)\, dT\, dm\Big|_{ent} - \int_0^{\min(T, T_{rq})} c_s(T)\, dT\, p(t)\, dt$$

$$+ \frac{m\beta' R_a T^*}{P}\, dP + m\beta' \mathcal{E}\, dt$$

where $k(T, T_{rq}) = 0; \; T > T_{rq}$

$= 1; \; T \le T_{rq}$.

On the left side of this equation, c_p is replaced by c_{pa} in the entrainment term, since the specific heat of entrained air is taken as that of dry air.

In the absence of condensation, the change in gas mass is entirely due to entrainment:

$$d(m\beta') = dm\Big|_{ent}$$

and that in condensed mass is entirely due to fallout:

$$d(m(1-\beta')) = -\,p(t)dt \; .$$

Using also the hydrostatic and gas laws, dividing by dt and rearranging terms, we find for the enthalpy balance

$$\frac{dT}{dt} = -\frac{\beta'}{\bar{c}_p(T)}\left[\frac{T^*}{T_e^*}\,gu + \left(\int_{T_e}^{T} c_{pa}(T)\,dT\right)\frac{1}{\beta' m}\,\frac{dm}{dt}\Big|_{ent} - \mathcal{E}\right] \qquad (1.4D)$$

where $\bar{c}_p(T)$ is the weighted mean specific heat of the cloud:

$$\bar{c}_p(T) = \beta' c_p(T) + (1-\beta')c_s(T)k(T, T_{rq}) \; .$$

The three terms in brackets on the right side of equation (1.4D) give the effects on temperature due to adiabatic expansion, entrainment, and dissipation of turbulent energy, respectively.

<u>Wet</u>

Since the temperature of the saturated cloud is at most 373° K, specific heats are taken as independent of temperature. When the cloud is saturated,

two additional enthalpy changes contribute to dH, namely latent heat absorbed by water evaporating to saturate entrained air, $-L(x - x_e)dm\Big|_{ent}$ and latent heat released by condensation of water,

$$- mLdx \frac{1 + s + w}{(1 + x + s + w)^2} .$$

Infinitesimal changes in m, s and w do not contribute to latent heat release.

It is no longer true that changes in gas mass and condensed mass are entirely due to entrainment and fallout respectively, as in the Dry stage, (unsaturated cloud). But water vapor lost from the gas mass through condensation appears as gained condensed mass. Therefore, the effect on enthalpy of water-vapor condensation is exactly compensated by latent-heat release, so that the derivation for the dry case may be modified to the wet case simply by the addition of the two latent heat terms to the enthalpy change dH.

Adding the two latent heat terms to dH, i.e. to the right side of the deriving equation as for the Dry stage, substituting equation (1.3W) for $\frac{dx}{dt}$, and using the definition of T^*, we find

$$\frac{dT}{dt} = - \frac{\beta'}{\frac{1 + L^2 x\epsilon}{\bar{c}_p R_a T^2} \frac{(1 + s + w)(1 + x/\epsilon)}{(1 + x + s + w)^2}}$$

$$\bullet \left[\left((T - T_e) \frac{c_{pa}}{\bar{c}_p} + \frac{L(x - x_e)}{\bar{c}_p} \right) \frac{1}{m\beta'} \frac{dm}{dt}\Big|_{ent} + \right.$$

$$\left. + \frac{T^*}{T_e^*} \frac{g}{\bar{c}_p} u \left(1 + \frac{Lx}{R_a T} \frac{(1 + s + w)}{(1 + x + s + w)} \right) - \frac{\mathcal{E}}{\bar{c}_p} \right]$$

where $\bar{c}_p$ is the weighted average of specific heats allowing for condensed water (specific heat, $c_{w\ell}$) and dry mass,

$$\bar{c}_p = \beta' c_p + \frac{s c_s k(T, T_{rq}) + w c_{w\ell}}{1 + x + s + w} .$$

By the time the cloud has cooled to the saturation point, the water-vapor and condensed-mass fractions of the cloud are so small that the weighted average specific heat, $\bar{c}_p$, and the specific heat of entrained air, c_{pa}, may both be replaced by the mean specific heat of the gas, c_p. Dropping the factors involving s and w in the equation for $\frac{dT}{dt}$, since these factors are approximately unity, we find

$$\frac{dT}{dt} = - \frac{\beta'}{1 + \frac{L^2 x \epsilon}{c_p R_a T^2}} \left[\left((T - T_e) + \frac{L(x - x_e)}{c_p} \right) \frac{1}{m\beta'} \left. \frac{dm}{dt} \right|_{ent} + \right.$$

$$\left. + \frac{T^*}{T_e^*} \frac{g}{c_p} u \left(1 + \frac{Lx}{R_a T} \right) - \frac{\mathcal{L}}{c_p} \right] . \qquad (1.4W)$$

CONDENSED WATER

Dry. Let w be the ratio of liquid and solid water mass to dry air mass, $w = m_{w\ell}/m_a$. Then,

$$w = 0 . \qquad (1.5D)$$

Wet. The liquid and solid water mass can change by:

1. Difference of the mixing ratio of entrained air and that of the saturated cloud, and
2. Condensation of vapor already in the cloud, and also by
3. Fallout of condensed water, so that

$$\frac{dm_{w\ell}}{dt} = \frac{x_e - x}{1 + x_e} \left.\frac{dm}{dt}\right|_{ent} - m_a \frac{dx}{dt} - \frac{w}{s + w} p(t)$$

where p(t) is the total rate of condensed mass fallout. By definition of w, since

$$dm_a = \frac{1}{1 + x_e} \left. dm \right|_{ent} ,$$

it follows that:

$$m_a \frac{dm}{dt} = - w \frac{dm_a}{dt} + \frac{dm_{w\ell}}{dt}$$

$$= - \left[\frac{w + x - x_e}{1 + x_e} \right] \left.\frac{dm}{dt}\right|_{ent} - m_a \frac{dx}{dt} - \frac{w}{s + w} p(t)$$

and since $m_a = \frac{m}{1 + x + s + w}$, then

$$\frac{dw}{dt} = - \frac{1}{\beta'} \left(\frac{1 + x}{1 + x_e} \right) \left(w + x - x_e \right) \frac{1}{m} \left.\frac{dm}{dt}\right|_{ent} - \frac{dx}{dt} - \frac{1 + x + s + w}{m} \left(\frac{w}{s + w} \right) p(t) \quad .$$

(1.5W)

By the time the cloud is saturated, s is certainly small, so that practically

$$\left.\frac{dm}{dt}\right|_{ent} = \frac{dm}{dt}$$

If s = 0, p = 0, then equation (1.5W) reduces to equation (3.6W) of Reference 1.1.

TURBULENT KINETIC ENERGY DENSITY

Turbulent kinetic energy per unit mass, E, is

1. generated from the mean flow (i.e., from kinetic energy of rise $u^2/2$) by
   a) eddy-viscous drag
   b) momentum-conserving inelastic-collision entrainment
2. diluted by entrainment
3. dissipated to heat, so that

$$\frac{dE}{dt} = 2k_2 \frac{T^*}{T_e^*} \beta' \frac{u^2 v}{H_c} + \frac{u^2}{2} \frac{1}{m} \left.\frac{dm}{dt}\right|_{ent} - E \frac{1}{m} \left.\frac{dm}{dt}\right|_{ent} - k_3 \frac{(2E)^{3/2}}{H_c} \qquad (1.6)$$

where the dissipation rate is

$$\mathcal{E} = k_3 \frac{(2E)^{3/2}}{H_c}$$

and k_3 is a dimensionless constant. Here, it is assumed that particles falling out of the cloud do not take any turbulent energy with them.

MASS

By differentiating the ideal gas law, we can express the rate of change of cloud mass via entrainment in terms of known cloud properties, viz.

$$\left.\frac{dm}{dt}\right|_{ent} = \frac{\beta' m}{V}\frac{dV}{dt} - \frac{\beta' m}{T}\frac{dT}{dt} + \frac{\beta' m}{P}\frac{dP}{dt} \; .$$

Considering the three terms on the right side, we find that the volume term can be evaluated from knowledge of cloud growth behavior that has been obtained from observations of nuclear clouds (see Appendix C.1), the temperature term can be obtained from equation (1.4D) or (1.4W), and the pressure term can be evaluated using the hydrostatic law (i.e., $\frac{dP}{dz} = -\rho_e g$).

<u>Dry</u>

$$\left.\frac{dm}{dt}\right|_{ent} = \frac{\dfrac{\beta' m}{T}}{1 - \dfrac{\beta'}{T^* \bar{c}_p}\displaystyle\int_{T_e}^{T} c_{pa}(T)\,dT} \bullet \left\{ \frac{S}{V}\mu v + \frac{\beta'}{T^* \bar{c}_p}\left[\frac{T^*}{T_e^*}\,gu - \mathcal{E}\right] - \frac{gu}{R_a T_e^*} \right\} \qquad (1.7D)$$

where $S = 4\pi R_c^2$, R_c is the horizontal cloud radius, and μ is the same as in equation (1.13).

Wet

$$\left.\frac{dm}{dt}\right|_{ent} = \frac{\beta' m}{1 - \frac{1}{T^*}\left[\frac{\beta'}{1 + \frac{L^2 x \epsilon}{c_p R_a T^2}}\right]\left[T - T_e + \frac{L(x - x_e)}{c_p}\right]}$$

$$\bullet \left\{\frac{S}{V}\mu v + \frac{\beta'/T^*}{1 + \frac{L^2 x \epsilon}{c_p R_a T^2}}\left[\frac{guT^*}{T_e^* c_p}\left(1 + \frac{Lx}{R_a T}\right) - \frac{\mathcal{E}}{c_p}\right] - \frac{gu}{R_a T_e^*}\right\} . \quad (1.7W)$$

PARTICLE FALLOUT

The rate of particle fallout, $p(t)$, is computed via the expression

$$p(t) = \pi R_c^2 \rho_p \sum_j f_j \left(\frac{\pi}{6} D_j^3\right) n(t)_j , \quad (1.8)$$

where ρ_p is particle density, D_j is particle diameter, $n(t)_j$ is the number of particles in the jth particle size class per unit volume of cloud, and R_c is horizontal cloud radius. The particle settling rate, f_j, is computed by Davies equations.[1.6] The summation is taken over the particle size classes.

NET MASS CHANGE

The net mass change is the sum of the mass change by entrainment and the mass change by fallout.

$$\frac{dm}{dt} = \left.\frac{dm}{dt}\right|_{ent} - p(t) \quad . \quad (1.9)$$

DRY CONDENSED MASS MIXING RATIO

In time, dt, a mass of dry air $\frac{1}{1+x_e} \, dm\Big|_{ent}$ is entrained, and a dry mass $\frac{s}{s+w} \, p(t)dt$ falls out. Then,

$$s(t+dt) = \frac{\frac{s}{1+s+x+w} m - \frac{s}{s+w} p(t)dt}{\frac{m}{1+s+x+w} + \frac{1}{1+x_e} dm\Big|_{ent}}$$

$$\frac{ds}{dt} = -\frac{1+s+x+w}{m} \, s \left[\frac{p(t)}{s+w} + \frac{1}{1+x_e} \frac{dm}{dt}\Big|_{ent} \right] . \qquad (1.10)$$

This can be written in the same form as equation (1.5W):

$$\frac{ds}{dt} = -\frac{1}{\beta'} \frac{1+x}{1+x_e} \, s \, \frac{1}{m} \frac{dm}{dt}\Big|_{ent} - \frac{1+x+s+w}{m} \left(\frac{s}{s+w}\right) p(t) . \qquad (1.10a)$$

CHARACTERISTIC VELOCITY

The characteristic velocity, v, is given by

$$v = \max \left(|u| , \sqrt{2E} \right) . \qquad (1.11)$$

Use of characteristic velocity instead of simple rise velocity allows entrainment and entrainment effects to continue after the upward motion of the cloud has ceased.[1.1]

VERTICAL WIND SHEAR

Wind shear operates on the cloud (it is assumed) by stretching it, thus increasing the cloud surface and increasing the total rate of entrainment. Instead of attempting to model wind-induced changes in cloud shape, therefore, it is practical to model directly the effect of shear on the entrainment rate. This treatment of wind shear was developed by Huebsch.[1.3]

It is proposed that shear increases the entrainment rate by an amount proportional to the product of (1) the magnitude of the wind-velocity difference, v_s, between the top and bottom of the cloud, and (2) the cloud vertical projected surface area, i.e., vertical cross-section. The choice of the magnitude, or absolute value, of shear, recognizes that the effect of shear on entrainment is irreversible. The vertical, instead of total, cloud area is chosen because horizontal wind motions can cause air to flow only through a vertical, not a horizontal, element of area.

The wind shear or velocity difference mentioned above is $v_s = \left| \vec{V}(z + H_c) - \vec{V}(z - H_c) \right|$ where $\vec{V}(z)$ is the wind vector at height z and H_c is the vertical radius of the cloud, and z is the height of the cloud center.

To account for effects of shear on the cloud rise we make simple modifications to the volume terms in equations (1.7D) and (1.7W). Namely,

$$\frac{S}{V} \mu v \longrightarrow \mu \left(\frac{S}{V} v + k_6 \frac{1.5}{R_c} v_s \right) . \tag{1.12}$$

Here k_6 is a non-dimensional constant, inserted for flexibility in computation, but normally taken as unity.

CLOUD FORM

Vertical Radius

At all times except the initial time, the vertical cloud radius is taken to be

$$H_c = \mu(z - z') \tag{1.13}$$

where μ is an empirically derived quantity (equation (1.18)), and z' is a constant for a particular case that is obtained from initial values of H_c and z via equation (1.13) (see equation (1.26)).

Volume

The cloud volume is computed via the ideal gas law equation as

$$V = R_a T^* \beta' m/P \ . \tag{1.14}$$

Horizontal Radius

We assume an oblate spheroidal shape for the cloud so that the horizontal radius is obtained from the volume and vertical radius as

$$R_c = \sqrt{3V/(4\pi H_c)} \tag{1.15}$$

EMPIRICAL PARAMETERS

Excluding those used exclusively to determine initial cloud properties, the model uses a number of dimensionless parameters that are determined either from observed cloud rise data alone or from comparisons of observed with calculated cloud rise data.

A parameter, k_2, the so-called eddy viscosity parameter, is used in equations (1.1) and (1.7). This parameter was originally taken to be a constant by Heubsch[1.7], but as a result of comparison of many observed with calculated stabilized clouds, (see Appendix A.2), we have determined that k_2 should be a function of yield. Our specification of k_2 is

$$\begin{aligned} k_2 &= 0.075 \ , & W &< 0.55 \text{ kT} \ , \\ k_2 &= 0.065W^{-0.24} \ , & W &\geq 0.55 \text{ kT} \ . \end{aligned} \tag{1.16}$$

The constant k_3, used in the equation for dissipation rate of turbulent kinetic energy density, equation (1.6), is given a value of 0.175. This is unchanged from the original model.[1.7]

A constant, k_6, taken to be unity, is included in the wind shear correction to the entrainment equation (see equation (1.12)).[1.3]

In their study of observed cloud rise data, Norment and Woolf[1.5] found that vertical cloud radius could be expressed as a linear function of cloud center altitude (equation (1.13)). The dimensionless yield dependent parameter μ, which also appears in equations (1.1), (1.7D) and (1.7W), was found to be

$$\mu = 0.092 W^{0.130} \quad . \tag{1.18}$$

Using the cloud rise model described in the first edition of this document, we executed cloud rise simulations for each of fifty test shots for which observed atmosphere structure and stabilized cloud data are available. Simulations for each shot were done over a range of values of F, the explosion energy fraction in the cloud at our initial time, such that a "best fit" F value could be assigned by least squares for each shot. From these "best fit" F values, a yield dependent general expression for F was obtained. Calculations with the revised model indicate that the expression does not need to be changed. We find that

$$F = 0.44 W^{0.014} \quad . \tag{1.19}$$

INITIAL CONDITIONS

A set of initial cloud properties has been derived mostly from the relations by Norment and Woolf which describe observed nuclear cloud rise data.[1.5] The reader is referred to reference 1.5 to find the origins of the expressions presented here. Units are in the mks system and W is explosion energy yield in kilotons equivalent of TNT.

CLOUD CENTER ALTITUDE

The initial cloud center altitude, z_i, is given by

$$z_i = h + 108W^{0.349} \tag{1.20}$$

where h is height of burst above mean sea level (msl).

CLOUD MASS AND VOLUME

Initially, the cloud mass is

$$m_i = m_{a,i} + m_{w,i} + m_r$$

where $m_{a,i}$ is initial air mass, $m_{w,i}$ is initial water mass, and m_r is initial soil mass. m_r is supplied by the Initial Conditions Module [1.8]; the other quantities are computed as follows.

$$m_{a,i} = \frac{\varphi \left[FW \left(4.18 \times 10^{12}\right) - m_r \int_{T_{e,i}}^{T_{r,i}} c_s(T)dT \right]}{\int_{T_{e,i}}^{T_i} c_{pa}(T)dT + x_e \int_{T_{e,i}}^{T_i} c_{pw}(T)dT} \tag{1.21}$$

$$m_{w,i} = \frac{(1-\varphi) \left[FW \left(4.18 \times 10^{12}\right) - m_r \int_{T_{e,i}}^{T_{r,i}} c_s(T)dT \right]}{\int_{T_{e,i}}^{T_i} c_{pw}(T)dT + L} + x_e m_{a,i} \tag{1.22}$$

where the initial temperatures for air and soil, T_i and $T_{r,i}$ are specified by the Initial Conditions Module, φ is the fraction of available energy used to heat air, and F is the fraction of the total explosion energy available to heat the air, water, and soil in the cloud (equation 1.19)). φ is specified in the input.

The initial cloud volume is obtained from the ideal gas law as

$$V_i = (m_{a,i} + m_{w,i}) R_a T_i^* / P \quad . \tag{1.23}$$

CLOUD SHAPE AND DIMENSIONS

Initially, the cloud is assumed to be an oblate spheroid with eccentricity, e, of 0.75. Therefore, we compute $R_{c,i}$ and $H_{c,i}$ as

$$R_{c,i} = \left(3V_i \Big/ \left[4\pi\sqrt{1 - e^2}\right]\right)^{1/3} \tag{1.24}$$

$$H_{c,i}^2 = R_{c,i}^2 \, (1 - e^2) \quad . \tag{1.25}$$

The parameter z' in equation (1.13) is evaluated at the initial time, and kept constant thereafter, from the expression

$$z' = z_i - H_{c,i}/\mu \quad . \tag{1.26}$$

RISE VELOCITY AND TURBULENT KINETIC ENERGY DENSITY

Initial cloud center rise velocity is given by

$$u_i = nkt_i^{n-1} \tag{1.27}$$

where

$$n = 0.409W^{0.071} \tag{1.28}$$

$$k = 595W^{-0.0527}$$

and t_i is the initial time supplied by the Initial Conditions Module.[1.8]
The turbulent kinetic energy is taken to be

$$E_i = u_i^2/2 \quad . \tag{1.29}$$

SUMMARY OF EQUATIONS USED FOR THE CLOUD RISE SIMULATIONS

DIFFERENTIAL EQUATIONS

Momentum

$$\frac{du}{dt} = \left\{ \left[\frac{T^*}{T_e^*} \beta' - 1 \right] g/(1-\mu) - \right.$$

$$\left. \left[\frac{2k_2 v}{H_c} \frac{T^*}{T_e^*} \beta' (1-\mu) + \frac{1}{m} \frac{dm}{dt} \right] u \right\} \frac{m}{m+m_i'} \tag{1.1}$$

Height

$$\frac{dz}{dt} = u \tag{1.2}$$

Water Vapor

$$\frac{dx}{dt} = - \frac{1+x+s}{1+x_e} (x - x_e) \frac{1}{m} \left. \frac{dm}{dt} \right|_{ent} \tag{1.3D}$$

$$\frac{1}{x} \frac{dx}{dt} = (1 + x/\varepsilon) \frac{L\varepsilon}{R_a T^2} \frac{dT}{dt} + (1 + x/\varepsilon) \frac{g}{R_a T_e^*} u \tag{1.3W}$$

Temperature

$$\frac{dT}{dt} = - \frac{\beta'}{\bar{c}_p(T)} \left[\frac{T^*}{T_e^*} gu + \left(\int_{T_e}^{T} c_{pa}(T) dT \right) \frac{1}{\beta' m} \left. \frac{dm}{dt} \right|_{ent} - \mathcal{E} \right] \tag{1.4D}$$

$$\frac{dT}{dt} = - \frac{\beta'}{1 + \frac{L^2 x \varepsilon}{c_p R_a T^2}} \left[\left((T - T_e) + \frac{L(x - x_e)}{c_p} \right) \frac{1}{m\beta'} \frac{dm}{dt}\bigg|_{ent} + \right.$$

$$\left. + \frac{T^*}{T_e^*} \frac{g}{c_p} u \left(1 + \frac{Lx}{R_a T} \right) - \frac{\mathcal{E}}{c_p} \right] \tag{1.4W}$$

Condensed Water

$$\frac{dw}{dt} = - \frac{1}{\beta'} \left(\frac{1 + x}{1 + x_e} \right) \left(w + x - x_e \right) \frac{1}{m} \frac{dm}{dt}\bigg|_{ent} - \frac{dx}{dt} - \frac{1 + x + s + w}{m} \left(\frac{w}{s + w} \right) p(t) \tag{1.5W}$$

Turbulent Kinetic Energy Density

$$\frac{dE}{dt} = 2k_2 \frac{T^*}{T_e^*} \beta' \frac{u^2 v}{H_c} + \frac{u^2}{2} \frac{1}{m} \frac{dm}{dt}\bigg|_{ent} - E \frac{1}{m} \frac{dm}{dt}\bigg|_{ent} - k_3 \frac{(2E)^{3/2}}{H_c} \tag{1.6}$$

Mass

$$\frac{dm}{dt}\bigg|_{ent} = \frac{\beta' m}{1 - \frac{\beta'}{T^* \bar{c}_p} \int_{T_e}^{T} c_{pa}(T)dT} \cdot \left\{ \frac{S}{V} \mu v + \frac{\beta'}{T^* \bar{c}_p} \left[\frac{T^*}{T_e^*} gu - \mathcal{E} \right] - \frac{gu}{R_a T_e^*} \right\} \tag{1.7D}$$

$$\left.\frac{dm}{dt}\right|_{ent} = \frac{\beta' m}{1 - \frac{1}{T^*}\left[\frac{\beta'}{1 + \frac{L^2 x\epsilon}{c_p R_a T^2}}\right]\left[T - T_e + \frac{L(x - x_e)}{c_p}\right]}$$

$$\bullet \left\{ \frac{S}{V} \mu v + \frac{\beta'/T^*}{1 + \frac{L^2 x\epsilon}{c_p R_a T^2}} \left[\frac{guT^*}{T_e^* c_p}\left(1 + \frac{Lx}{R_a T}\right) - \frac{\mathcal{E}}{c_p}\right] - \frac{gu}{R_a T_e^*} \right\} . \qquad (1.7W)$$

Particle Fallout

$$p(t) = \pi R_c^2 \rho_p \sum_j f_j \left(\frac{\pi}{6} D_j^3\right) n(t)_j \qquad (1.8)$$

Net Mass Change

$$\frac{dm}{dt} = \left.\frac{dm}{dt}\right|_{ent} - p(t) \ . \qquad (1.9)$$

Dry Condensed Mass Mixing Ratio

$$\frac{ds}{dt} = - \frac{1}{\beta'} \frac{1 + x}{1 + x_e} s \frac{1}{m} \left.\frac{dm}{dt}\right|_{ent} - \frac{1 + x + s + w}{m} \left(\frac{s}{s + w}\right) p(t) \qquad (1.10a)$$

Characteristic Velocity

$$v = \max\left(|u|, \sqrt{2E} \right) . \qquad (1.11)$$

Vertical Wind Shear

To account for effects of shear on the cloud rise we make simple modifications to the volume terms in equations (1.7D) and (1.7W). Namely,

$$\frac{S}{V}\,\mu v \rightarrow \mu\left(\frac{S}{V}\,v + k_6\,\frac{1.5}{R_c}\,v_s\right) . \tag{1.12}$$

CLOUD FORM

$$H_c = \mu(z - z') \tag{1.13}$$

$$V = R_a T^* \beta' m/P \quad . \tag{1.14}$$

$$R_c = \sqrt{3V/(4\pi H_c)} \tag{1.15}$$

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APPENDIX A.1
LIST OF SYMBOLS

A NOTE ON NOTATION

This report uses hydrodynamics, thermodynamics and meteorology. These fields use the same symbols for different quantities; consequently, any notation must violate some usage. For example, in meteorology x and w are used for ratios of vapor-and liquid-water mass to dry air mass, respectively. But in hydrodynamics the velocity components u, v, w correspond to the coordinates x, y, z. Since z is the usual symbol for the vertical coordinate, as in $dP = -\rho_e g\, dz$, inconsistency cannot be avoided.

SYMBOLS

c_p	specific heat of gas at constant pressure
c_s	specific heat of dry condensed matter
D_j	fallout particle diameter in the jth particle size class
E	turbulent kinetic energy per unit mass
e	eccentricity of ellipse
f_j	still-air settling rate of particles in the jth particle size class
F	fraction of explosion energy, W, contained in fireball at start of rise (equation (1.19))
g	acceleration of gravity
H	enthalpy
H_c	vertical radius of the nuclear cloud

k_2	dimensionless empirical parameter (in eddy-viscosity) (equation (1.16))
k_3	dimensionless empirical constant (in dissipation rate)
L	latent heat of vaporization of water or ice
m	mass of cloud
m'	virtual mass
m_r	initial mass of refractory matter
$n(t)_j$	number of particles per unit cloud volume in the jth particle size class
P	pressure
p(t)	rate of soil fallout
q(x)	$\frac{1 + x/\epsilon}{1 + x}$
R_a	gas constant of air, i.e., universal gas constant divided by mean molecular weight of dry air
R_c	horizontal radius of the nuclear cloud
s	dry condensed mass in cloud per unit dry air mass
T	temperature
T*	Tq(x), i.e., virtual temperature
T_r	condensation temperature of refractory matter
T_{rq}	initial mean temperature of condensed matter in cloud (applicable to land-surface-bursts)
t	time
u	vertical velocity of cloud
V	volume of cloud
v	characteristic velocity, $v = \max(\lvert u \rvert, \sqrt{2E})$
W	total explosion energy (kilotons)
w	liquid and solid water mass per unit dry air mass

x	mixing ratio (water vapor mass per unit dry air mass)
z	vertical coordinate
β'	ratio of gas density to total density of cloud = $\frac{1+w}{1+x+s+w}$
$\mathcal{E}$	energy dissipation rate per unit mass
ϵ	ratio of molecular weights of water and air 18/29
μ	empirical parameter used to determine vertical cloud radius (equation 1. 18))
ρ_e	ambient air density
ρ_p	fallout particle density
φ	fraction of available fireball energy used to heat air

<u>Subscripts</u>

a	air (dry air)
e	ambient (environment) conditions
ent	entrainment
ext	external
i	initial value
j	specifies a particle size class
r	refractory matter
rq	equilibrium temperature of refractory matter
rs	dry m [illegible]
w	water or water vapor
wv	water vapor
$w\ell$	liquid and solid water (i.e., water and ice)

APPENDIX B.1

THE MOMENTUM EQUATION

In the DELFIC cloud rise model, the nuclear cloud is treated as a buoyant, entraining, hot bubble of air that is laden with a certain quantity of soil particles. To obtain the equation of motion of the cloud, in terms of rate of rise of its center, we must set up a momentum balance equation and solve this for the cloud center acceleration.

According to potential flow theory, a body accelerating through a fluid causes a net displacement in position of a mass m' of the fluid[B.1.1]. (For a sphere, $m' = \frac{1}{2}\rho_e V$.) This fluid displacement effectively increases the momentum of the body, so that in computing its momentum, the mass m', called the virtual mass, must be added to the mass of the body. In the DELFIC cloud rise model, m' is given a constant value equal to $\rho_{e,i} V_i/2$.

The rate of momentum change of the cloud is equal to the buoyant force on the bubble minus the drag force, viz.

$$\frac{d}{dt}(mu + m'u) = V(\rho_e - \rho)g - \frac{2k_2}{H_c}\frac{\rho_e}{\rho} vum \quad \text{(B.1.1)}$$

Now, if we perform the differentiation indicated on the left side, divide both sides by m, and note that

$$\frac{\rho_e}{\rho} = \frac{T^*}{T_e^*}\beta' ,$$

we obtain Huebsch's original expression[B.1.2]

$$\frac{du}{dt} = \left\{\left[\frac{T^*}{T_e^*}\beta' - 1\right] g - \left[\frac{2k_2 v}{H_c}\frac{T^*}{T_e^*}\beta' + \frac{1}{m}\frac{dm}{dt}\right] u\right\}\frac{m}{m+m'_i} \cdot \quad \text{(B.1.2)}$$

In deriving equations (B. 1. 1) and (B. 1. 2) certain assumptions are made implicitly that we now need to recognize. In these equations we assume that we are following the motion of the center of gravity of the cloud. We also assume that growth of the cloud by entrainment of ambient air is symmetric about the cloud center. Actually, since we have no definite knowledge of the location of the center of gravity of the cloud, we chose to consider the geometric center as being equivalent to the center of gravity. This in itself will inevitably lead to some prediction error, but in any case, the assumption of symmetric entrainment need not be made since this can easily be corrected for.[B. 1. 3]

Entrainment asymmetry arises because most if not all entrainment must occur above the level of the cloud center. If this were not true, it would mean that ambient air entrained below would need to chase, and catch up with, the rising cloud. Thus we assume entrainment occurs via inelastic collision with, and absorption of, ambient air.

If we consider the growth of a nuclear cloud over a short time interval Δt, and assume all the entrainment occurs in the upper half of the cloud, we find that the cloud center height will increase because of the asymmetric entrainment alone. In Figure B. 1. 1 the smaller ellipse represents a vertical cross section of a cloud at time t and the larger ellipse represents the same cloud at $t + \Delta t$. The upward motion of the cloud bottom has been subtracted in the figure. We see that if the vertical radius increases by ΔH_c, the apparent cloud center height also increases by ΔH_c, and that this would occur even if the momentum of the cloud were zero. The velocity that appears in equation (B.1.1) is relevant only to the motion of the cloud from its momentum, whereas the observed velocity includes also the apparent rise from the entrainment growth. Thus the apparent rise velocity is given by

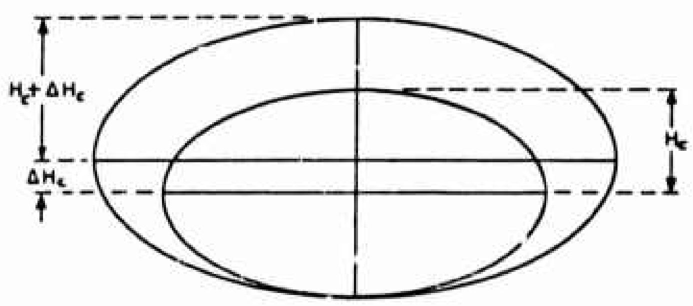

Figure B. 1. 1 Apparent Increase in Cloud Center Height Resulting from Asymmetric Entrainment.

$$u_a = u + \frac{dH_c}{dt} \quad . \qquad (B. 1. 3)$$

The rate of change of H_c, readily derived by differentiation of equation (1.13), is μu_a. We then obtain for the momentum velocity

$$u = u_a(1 - \mu) \quad . \tag{B.1.4}$$

When this is substituted in equation (B.1.1), and the resulting equation is solved for the cloud center acceleration, we find

$$\frac{du}{dt} = \left\{ \left[\frac{T^*}{T_e^*} \beta' - 1 \right] g/(1-\mu) - \left[\frac{2k_2 v}{H_c} \frac{T^*}{T_e^*} \beta \ (1-\mu) + \frac{1}{m} \frac{dm}{dt} \right] u \right\} \frac{m}{m+m_i'} \tag{B.1.5}$$

where we have dropped the subscript a on the u. Notice that we have applied the $(1-\mu)$ factor to the characteristic velocity, v, as well as to u. This is done because v acts as a rise velocity in evaluation of the drag force on the cloud (see eq. (B.1.1)).

Table B.1.1 gives illustrative values of the factor $1 - \mu$ as computed from equation (1.18). Obviously, for high yield shots this factor is quite significant.

TABLE B.1.1

Values of $1 - \mu$ for Selected Explosion Energy Yields

W(kT)	$1 - \mu$
.01	.949
.1	.933
1	.908
10.	.876
100.	.833
1,000.	.774
10,000.	.695
100,000.	.589

REFERENCES

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B.1.2 I. O. Huebsch, "The Development of a Water-Surface-Burst Fallout Model: The Rise and Expansion of the Atomic Cloud," NRDL-TR-741 (23 April 1964). AD-441 983.

B.1.3 H. G. Norment and S. Woolf, "Studies of Nuclear Cloud Rise and Growth," TO-B 66-9 (21 October 1966). AD-382 034 Secret-FRD.

APPENDIX C.1
THE ENTRAINMENT EQUATION

In the original cloud rise model, Huebsch uses an entrainment equation (equation 3.8 of reference C.1.1) that consists of a single term which corresponds to the first term on the right of equations (1.7D) and (1.7W) above. This relation was found to yield acceptable cloud rise simulations, particularly in terms of the stabilized cloud properties, and its acceptance is based on this excellent criterion. On the other hand, the study by Norment and Woolf of observed cloud rise behavior[C.1.2] has led to an empirical understanding of the basis of the Huebsch relation, and it has shown that the relation actually is inadequate to describe entrainment by the early cloud. In this appendix, we will show now a more correct entrainment equation can be derived from the ideal gas law and observed cloud behavior, and how the Huebsch entrainment equation relates to this.

DERIVATION OF THE ENTRAINMENT EQUATION

Let us begin with the well-known equations for expressing rate of change of volume and temperature in an ideal gas hot bubble rising through an ideal gas hydrostatic atmosphere.

$$\frac{1}{T}\frac{dT}{dt} = -\left(1 - \frac{\rho}{\rho_e}\right)\frac{1}{m}\frac{dm}{dt} + \frac{1}{P}\frac{dP}{dt}\frac{R}{C_p} \qquad (C.1.1)$$

$$\frac{1}{V}\frac{dV}{dt} = \frac{1}{m}\frac{dm}{dt} + \frac{1}{T}\frac{dT}{dt} - \frac{1}{P}\frac{dP}{dt} \qquad (C.1.2)$$

where

T	=	average cloud temperature
ρ	=	average cloud density
ρ_e	=	density of the ambient atmosphere
m	=	total cloud mass
P	=	pressure (we assume pressure equilibrium with the atmosphere)
t	=	time
$\mathcal{R}$	=	molar ideal gas law constant
C_P	=	molar heat capacity at constant pressure
V	=	total cloud volume.

To avoid algebraic complications that result from including soil and water vapor, we will assume an air burst in a dry air environment at low altitude. To obtain the entrainment equation, we rearrange equation (C. 1. 2) and multiply through by m to obtain

$$\frac{dm}{dt} = \rho \frac{dV}{dt} - \frac{m}{T} \frac{dT}{dt} + \frac{m}{P} \frac{dP}{dt} . \qquad (C.1.3)$$

Next let us assume an oblate spheroidal shape for the cloud (i. e. $V = \frac{4}{3} \pi R_c^2 H_c$) so that

$$\frac{1}{V} \frac{dV}{dt} = \frac{2}{R_c} \frac{dR_c}{dt} + \frac{1}{H_c} \frac{dH_c}{dt} \qquad (C.1.4)$$

where H_c and R_c are the vertical and horizontal cloud radii respectively. Studies of cloud rise data show that for times less than about two or three minutes (depending on yield)

$$R_c = \lambda (z - z_1) \tag{C.1.5}$$

$$z - z_1 = kt^n \tag{C.1.6}$$

and up to stabilization time

$$H_c = \mu (z - z_2) \tag{C.1.7}$$

where z is the cloud center height and λ, μ, z_1, z_2, k, and n are constants that can be determined from cinefilms for particular shots. By combining equations (C.1.5) and (C.1.6) we get

$$R_c = \lambda kt^n \tag{C.1.8}$$

and from equations (C.1.6) and (C.1.7) we get

$$H_c = \mu kt^n + \mu(z_1 - z_2). \tag{C.1.9}$$

Now, on substituting equations (C.1.8) and (C.1.9) into equation (C.1.4) we obtain

$$\frac{1}{V}\frac{dV}{dt} = \frac{2n}{t} + \frac{nkt^{n-1}}{kt^n + z_1 - z_2} \quad . \tag{C.1.10}$$

Next, by differentiation of equation (C. 1. 6) we obtain the cloud rise velocity, u

$$u = \frac{n(z - z_1)}{t} , \tag{C. 1. 11}$$

and substitution of this into equation (C. 1. 10) followed by multiplication through by V yields

$$\frac{dV}{dt} = \frac{Vu}{z - z_1} \left[2 + \frac{1}{1 + (z_1 - z_2) / (z - z_1)} \right] . \tag{C. 1. 12}$$

Substitution of equation (C. 1. 12) into equation (C. 1. 3) yields finally

$$\frac{dm}{dt} = \frac{\rho u V}{z - z_1} \left[2 + \frac{1}{1 + (z_1 - z_2) / (z - z_1)} \right] - \frac{m}{T} \frac{dT}{dt} + \frac{m}{P} \frac{dP}{dt} \tag{C. 1. 13}$$

which is our basic entrainment equation.

To express this in a form that can be related to the entrainment equation given by Huebsch, we need only require that $z_1 = z_2$. (As noted in reference C.1.2 this is frequently true, but in virtually all cases, even at early times when z is small,

$$\left| \frac{z_1 - z_2}{z - z_1} \right| << 1$$

and can be neglected.) Then since $V = \frac{4}{3} \pi R_c^2 H_c$ and we assume $H_c \approx \mu(z - z_1)$ (see equation (C. 1. 7)), we obtain

$$\frac{dm}{dt} = 4 \pi R_c^2 \mu \rho u - \frac{m}{T} \frac{dT}{dt} + \frac{m}{P} \frac{dP}{dt} .$$

or

$$\frac{dm}{dt} = m \frac{S}{V} \mu u - \frac{m}{T} \frac{dT}{dt} + \frac{m}{P} \frac{dP}{dt} \qquad \text{(C. 1. 14)}$$

where $S = 4 \pi R_c^2$. Comparison of this equation with equation (3. 8) of reference C. 1. 1, the Huebsch entrainment equation, shows that if we neglect the second and third terms on the right hand side of equation (C. 1. 14), we have an equation that is equivalent to that of Huebsch*. Furthermore, the Huebsch parameter λ is indicated to be equivalent to our parameter μ and, if this is true, should be a function of explosion energy yield,

$$\mu = 0.092\ W^{0.130}, \qquad \text{(C. 1. 15)}$$

where W is in units of kilitons. Huebsch has used a constant value of 0. 25 for this parameter.

SIGNIFICANCE OF THE ADDITIONAL ENTRAINMENT EQUATION TERMS

It is easy to show, though we shall not go through the calculations here, that when the cloud is hot (i. e., when $T >> T_e$), the temperature term in equation (C. 1. 14) actually dominates the entrainment. Thus, neglect of the temperature term results in a gross underestimation of the entrainment rate under this condition. By referring to equation (C. 1. 1) it is easy to see that if the entrainment rate is incorrect, the cooling rate is affected directly. Again, it is easy to show, via simple calculations, that when $T >> T_e$ the cooling rate is indeed drastically in error. For example, for a cloud at 3000° K, under expected conditions, the fractional cooling rate (i. e., $\frac{1}{T} \frac{dT}{dt}$) of the old model, when compared with the revised model, is too low by a factor of almost four.

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* Equation (3. 8) of Huebsch contains a turbulent kinetic energy contribution to the velocity factor (see equation 2. 8 of reference C. 1. 1), however, at early times this contribution is negligible and is, I believe, ignored (see section 2. 6. 3 of reference C. 1. 1)

With regard to the pressure term that appears in equation (C. 1. 14), its contribution seems to be quite small relative to the other terms at all times. Thus, its neglect in the prior version of the model should not have significantly influenced the simulation results.

TURBULENT KINETIC ENERGY AND ENTRAINMENT

The use of turbulent kinetic energy density to control late cloud rise and growth is a major attraction of the Huebsch cloud rise model. Fortunately, there is no reason why the revised version of the model cannot incorporate turbulence effects in a manner analogous to that used previously. This is done simply by replacing the cloud rise velocity in equation (C. 1. 14) by the "characteristic speed," v,

$$v = \max\left(|u|, \sqrt{2E}\right) \quad .$$

This has been done in equations (1. 7D) and (1. 7W) above.

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PART 2

CLOUD RISE MODULE

INTRODUCTION

The Cloud Rise Module computer code has been thoroughly revised and reorganized. The revisions, for the most part, reflect the basic changes in the model that are discussed in Part 1 of this document. In terms of its effect on the code, certainly the change with most far reaching effect is the deletion of the particle growth capability. This deletion has allowed the elimination of several whole subroutines, it has allowed use of a single, arbitrary tabular representation of the fallout particle size spectrum, which is provided by the Initial Conditions Module, and it has made much easier the work of reorganization and tidying of the code.

Several changes that do not affect the cloud rise simulations per se, but are of fundamental importance to subsequent atmospheric transport and output processing, have been made in subroutine RSXP. These changes are as follows:

1. In the old model, all output particle wafers have square shaped horizontal cross-sections with an edge length that is equal for all wafers. In the old model it is necessary to subdivide all large wafers in the horizontal plane, and the wafer edge length is determined by the number of horizontal wafer subdivisions that are specified by the user. In the new model it is possible to subdivide wafers in the horizontal plane as before, but no longer is it necessary to do so. Now wafers of any horizontal dimensions are acceptable to the Transport Modules and the Output Processor Module of DELFIC.

2. In the previous model, output particle wafers have no vertical thickness; each wafer's contents are projected on to the horizontal plane that passes through its center. In the new model, each wafer maintains its vertical thickness throughout the cloud rise computation, and it is described in the output as a three-dimensional entity.

3. In the new model the rise and growth of the top and bottom of each particle wafer is computed

> independently. This allows the wafer geometry to be determined in a physically realistic manner. Thus, should the bottom of a wafer settle out of the cloud cap before the cap has attained its final height and size, while the wafer top remains inside the cloud, then the wafer top and bottom not only can be separated by a considerable distance in the vertical, but also they can be very different in their horizontal dimensions. The new model has been designed to cope with these situations. The precise means used is described here. A corollary change allowed by this new feature is that it is no longer necessary or desirable to reduce below-cloud wafer radii by an unrealistic "stem shrinkage factor" (see equation (2. 19) of the first edition of DASA-1800-III).

In Appendix A. 2 we present some simulated stabilized cloud data and we compare these with observations. In addition, a complete cloud rise history for a 15MT surface shot is given in graphical form.

METHOD OF CALCULATION

The basic differential equations used to describe the cloud rise and growth have been described in Part 1 and will not be repeated. We are concerned here with specific numerical procedures and geometric constructs used in the Cloud Rise Module calculations. These calculations are divided into two major parts. The first is carried out by subroutine CRM and its associated programs; the second is carried out by subroutine RSXP. CRM computes the cloud rise and growth as described in Part 1 and, in the process, compiles a time-history table of cloud properties (array CX(I, J)). After the complete execution of CRM, the cloud rise history table, CX(I, J), is used by subroutine RSXP to resimulate the cloud rise for the purpose of setting up a list of particles-aloft for input to the Transport Modules. Details concerning cloud structure are somewhat different for the two parts of the calculation. For this reason we consider the methods used during these calculations separately. It should always be borne in mind that the CRM calculation results are used to construct array CX, which then forms the basis for the RSXP calculations,

and the only communication between the CRM and RSXP calculations is via this array and the particle-size mass-frequency distribution.

BUOYANT CLOUD RISE: THE CALCULATIONS OF SUBROUTINE CRM

Initial Conditions

Explosion yield, height of burst, initial time, initial temperature, soil burden, soil solidification temperature, and a particle size distribution table are supplied by the Initial Conditions Module (see DASA-1800-II).

Other initial conditions, such as cloud center height, fraction of explosion energy in the cloud, cloud volume, and vertical and horizontal radii of the cloud are computed as indicated in Part 1.

Physical Quantities

Specific heats of air, water, and soil are computed by the following equations (joules/(kg - °K))

$$c_{pa} = 946.6 + 0.19710T, \quad T \le 2300^\circ K \tag{2.1}$$
$$c_{pa} = -3587.5 + 2.125T, \quad T > 2300^\circ K$$

$$c_{pw} = 1697.66 + 1.144174T \tag{2.2}$$

$$c_s = 781.6 + 0.5612T - 1.881 \times 10^7/T^2, \quad T \le 848^\circ K \tag{2.3}$$
$$c_s = 1003.8 + 0.1351T, \quad T > 848^\circ K \ .$$

The specific heat equations for air and water were derived from data in the NBS Gas Tables[2.1]. The specific heat equations for soil are those given by Kelly for silica.[2.2]

The latent heat of vaporization of water from liquid to vapor is 2.5×10^6 joules/kg, and from ice to vapor is 2.83×10^6 joules/kg.[2.3] The heat energy equivalent of one kiloton of explosion energy is 4.18×10^{12} joules.

The ideal gas law constant for air is taken as 287 joules/(kg - °K), and the acceleration of gravity is $9.8 \mathrm{m/sec}^2$.

The water vapor mixing ratio in the atmosphere external to the cloud, x_e, is computed from the expression

$$x_e = \frac{109.98 H_R}{29P} \left(\frac{T_e}{273} \right)^{-5.13} \exp \left[25 \left(\frac{T_e - 273}{T_e} \right) \right], \tag{2.4}$$

where T_e is the temperature of the atmosphere external to the cloud, H_R is the relative humidity (per cent), and P is the pressure (newtons per square meter). Saturation water vapor pressure in the cloud is computed from the expression

$$P_{ws} = 611 \left(\frac{T}{273} \right)^{-5.13} \exp \left[25 \left(\frac{T - 273}{T} \right) \right]. \tag{2.5}$$

Atmosphere Structure

The Cloud Rise Module makes use of a tabular description of the properties of the atmosphere through which the cloud is to rise. A tabulated description of atmospheric properties vs. height must be supplied to the Cloud Rise Module, but great latitude exists with regard to the heights at which properties may be specified, the formats, order, and units in which the values of property parameters may be furnished, and even the availability of certain parameters. The tabulated quantities required (but not all necessarily supplied in the input) are altitude, temperature, density, viscosity, pressure, and relative humidity. Also included with these tables are acceleration of gravity and mean free path. The atmospheric description derived from the input data extends from -1000 to 50,000 m in increments of 200m. Complete details are given in the discussion of subroutine "CRD and in the User Information Section.

Wind Data

To compute the effect on the cloud rise of wind shear requires availability of the altitude profile of winds. These winds are input via the

Initial Conditions Module. Wind shear affects are computed via the method described on p. 16. Wind components at any altitude are evaluated by linear interpolation with altitude in the wind data table.

Particle Size Spectra

The Cloud Rise Module receives a tabular representation of a fallout particle size-mass fraction distribution from the Initial Conditions Module. The distribution is resolved into so-called particle size classes such that each table entry contains data pertinent to one size class. The data are: central particle diameter for the size class, upper and lower boundary diameters for the size class, and the mass fraction of the total soil burden that occurs within the size class. The central particle diameter is the geometric mean of the boundary diameters. Particle density is input via COMMON/SET1/.

The Initial Conditions Module can construct tables for two analytical distribution forms, lognormal and power law, from the required function parameters and a specification of the number of size classes desired (see DASA 1800-II and its recent addenda). It also can accept distribution data already resolved into tabular form so that it is not necessary that one of the analytical distributions be used.

Loss of Soil Material from the Rising Cloud

The amount of material lost for each particle size class is computed after each time increment and the in-cloud particle distribution is adjusted accordingly. The cloud particle content is assumed to be uniformly distributed through the cloud at all times. No attempt is made to follow the free air settling of soil mass increments subsequent to their departure from the cloud. The computed loss of soil material directly affects the cloud byoyancy and in-cloud particle distribution and indirectly affects the cloud trajectory and temperature history.

Numerical Integration

A fourth order Runge-Kutta method is used for integrating the differential equations for the various cloud rise and growth processes. This

method requires four evaluations of the differential equations for each time step. Given a quantity f_t at time t with differential $(df/dt)_t$, the method proceeds to evaluate $f_{t+\Delta t}$ at time $t + \Delta t$ via the algorithm:

$$f_1 = f_t + \frac{\Delta t}{2}\left(\frac{df}{dt}\right)_t$$

$$G_1 = \left(\frac{df}{dt}\right)_t$$

$$f_2 = f_1 + \left(\frac{2 - \sqrt{2}}{2}\right) \Delta t \left[\left(\frac{df}{dt}\right)_1 - G_1\right]$$

$$G_2 = (2 - \sqrt{2})\left(\frac{df}{dt}\right)_1 + \left(\frac{3}{2}\sqrt{2} - 2\right) G_1$$

$$f_3 = f_2 + \left(\frac{2 + \sqrt{2}}{2}\right) \Delta t \left[\left(\frac{df}{dt}\right)_2 - G_2\right]$$

$$G_3 = (2 + \sqrt{2})\left(\frac{df}{dt}\right)_2 - \left(2 + \frac{3}{2}\sqrt{2}\right) G_2$$

$$f_{t+\Delta t} = f_3 + \frac{\Delta t}{6}\left[\left(\frac{df}{dt}\right)_3 - 2G_3\right] . \tag{2.6}$$

Fixed time steps of 1/16, 1/2, and 5 sec are used according to the schedule:

$t - t_i < 1$ sec,	$\Delta t = 1/16$ sec
$1 \le t - t_i < 100$,	$\Delta t = 1/2$
$100 < t - t_i$,	$\Delta t = 5$

where t_i is the initial time.

Cloud Rise History Table, CX

It is not practical to record for storage all of the required cloud properties at each time step during the CRM calculations. Instead, a time history table, CX, is compiled at more widely spaced time intervals. The quantities stored are time, cloud bottom altitude, cloud top altitude, radius, temperature, and gas density at the recorded time; also stored is the time interval to the next table entry and the average rates of cloud base and top rise during this interval. These rates are computed by differencing the appropriate CX entries and dividing by the time increment.

The CX table entries are made at times specified as follows. The first entry is made at the initial time, t_i. For the nth table entry, t_n is given approximately by

$$t_n = t_i + \frac{n(n-1)(n+4)}{6}\left(\frac{e}{m}\right) , \qquad n > 1 , \tag{2.7}$$

where e is the base of the Naperian logarithm and m is currently given the value 52. If the user knows, or can estimate, t_i and the cloud stabilization time (the maximum t_n), he can adjust the number of entries in the CX table to any desired value by solving equation (2.7) for m. The new factor e/m is then applied in subroutine CXPN at statement 62 + 1.

Soil Solidification Time

The time at which the average cloud temperature reaches the soil solidification temperature is of fundamental importance to the Particle Activity Module calculation (see DASA-1800-V). This time is determined (subroutine LINE2) by linear interpolation in the CX table after the cloud rise is completed.

Programmed Stops

There are six programmed stops in the cloud rise calculations. The particular switch used to stop the calculations always is identified in the

output. For five of the switches the output identification is

CLOUD RISE IS TERMINATED IN $\left\{ \begin{matrix} \text{DCSN} \\ \text{CXPN} \end{matrix} \right\}$ AT STATEMENT $\left\{ \text{XXXX} \right\}$ BY THE $\left\{ \text{WORD} \right\}$ SWITCH.

DCSN or CXPN is the name of the relevant subroutine, XXXX is the appropriate FORTRAN statement number to be found in the card listings, and WORD is the switch identifier as given in the following descriptions of the switches:

1. Radius expansion switch (WORD R RATE)

   Cloud rise is stopped when the inequality

$$\left| \ell n \left(\frac{R_n}{R_{n-1}} \right) \right| \Big/ (t_n - t_{n-1}) < \text{TSRD} \tag{2.8}$$

is satisfied, where

$$\text{TSRD} = \exp \left[0.014778 \, \ell n(W) - 7.0499 \right] \quad , \tag{2.9}$$

W is the explosion yield in kilotons, R is the horizontal cloud radius, and t is time. The subscript n refers to the nth entry in the CX array table (see the Cloud Rise History Table section). This is a normal termination.

2. Run-away switch (WORD ≡ ZLMT)

Cloud rise is stopped when the inequality

$$z > ZLMT \tag{2.10}$$

is satisfied, where

$$ZLMT = 10^4 \ W^{1/4} \ ; \tag{2.11}$$

z is cloud center height and W is explosion yield in kilotons. This is an abnormal termination.

3. Temperature switch (WORD ≡ TEMP)

Cloud rise is stopped when the inequality

$$T < 10 \tag{2.12}$$

is satisfied, where T is the average cloud temperature in degrees Kelvin. This is an abnormal termination.

4. CX array overflow switch (WORD ≡ MCX)

Cloud rise is stopped when the inequality

$$MCX > 90 \tag{2.13}$$

is satisfied. MCX is the CX array entry counter. This is an abnormal termination.

5. Minimum radius switch (WORD ≡ R. LT. 1)

Cloud rise is stopped when the inequality

$$R < 1 \tag{2.14}$$

is satisfied, where R is the horizontal cloud radius. This is an abnormal termination.

The sixth switch is used to terminate the cloud rise if a negative particle number density (number/unit cloud volume) is found. A comment

NEGATIVE PARTICLE DENSITY

is printed.

GENERATION OF THE PARTICLES ALOFT LIST: THE CALCULATIONS OF SUBROUTINE RSXP

As described previously, the RSXP calculations consist of a second pass through the cloud rise using the cloud rise history table, CX. During these calculations particle inputs are prepared for the transport calculations. In subroutine RSXP no accounting is made of the horizontal movements of particles during the cloud rise; such corrections are applied to each cloud subdivision by subroutine WNDSFT of the Cloud Rise-Transport Interface Module.

Cloud Structure

Throughout the RSXP calculations the cloud is taken to have a cylindrical structure with radius, top height, and bottom height taken from the CX array.* At the initial time, the cloud is subdivided by a set of horizontal planes into an arbitrary specified number of subcylinders as shown in Figure 2.1. A geometrically identical and co-located set of such spatial subdivisions is defined for each particle size class. Hereafter we shall call these subdivisions wafers. The number of wafers per particle size class is the same for each particle size class and is specified by an input integer KDI. If the input

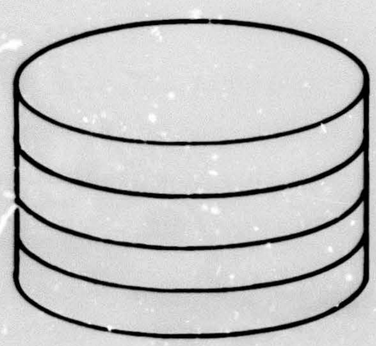


Figure 2.1. Subdivision of the Initial-Time Cloud Cylinder into Four Wafers.

*The CX Array entries are calculated for an oblate spheroidal cloud in the CRM calculations.

value of KDI ≤ 0, a value of KDI is supplied by the program as

$$KDI = INT\left[1.0 + (z_{T,max} - z_{B,max})/100.0\right] \qquad (2.15)$$

or KDI = 3, whichever is greater, where $z_{T,max}$ and $z_{B,max}$ are the final cloud top and bottom altitudes in the CX array in units of meters, and INT means "the integral part of . . . ."

The parameters used to describe each wafer at any time are the altitude and radius of its top, the altitude and radius of its base, its particle size, and the mass of its fallout content.

To describe how subroutine RSXP computes the particles aloft distributions, let us consider the computations for a single particle size class, and keep in mind that the calculations are repeated for all of the remaining particle size classes. The calculations begin at the initial time with a wafer configuration as illustrated by Figure 2.1. In these calculations the central particle diameter for the size class is not used; instead the size class boundary particle diameters are used, with the heaviest particle assigned to the bottom of each wafer and the lightest particle assigned to each wafer top. Thus, the wafer tops and bottoms are processed in pairs throughout the portion of the calculations that pass the CX array.

Beginning at the initial time, the calculations proceed in time through the CX array so that at each new time unique cloud cap base altitudes, top altitudes, and radii are defined. At each time, the still air gravity settling rate is computed for each wafer top or bottom, and this velocity component is subtracted from its rise velocity, which is computed as described in the next section, so that each wafer top or bottom has a non-zero vertical velocity component relative to the cloud cap center.

When a wafer top or bottom falls through the base of the cloud cap, its radius is taken as the radius of the cloud cap at the time of its fallout, and its radius is kept at this value henceforth.

If it is found that both the top and bottom of a wafer are still within the

cloud cap at stabilization time, then both have radii equal to the final cloud cap radius, and the volume of the wafer is taken to be the volume of a right circular cylinder of height equal to the difference between the altitudes of wafer top and bottom. However, if it is found that the bottom or top, or both, of a wafer is below the cloud at stabilization time, then, to account for the difference in radii between the wafer top and bottom requires some additional complexity in the calculations and requires further subdivision of the wafer. To take this variation of radius with altitude into consideration, the following scheme is employed:

The space between the top and bottom of the wafer is subdivided into n volumes

$$n = \mathrm{INT}\left(R_T / R_B \right) \tag{2.16}$$

where R_T and R_B are the radii of the top and bottom of the wafer, respectively, as shown in Figure 2.2. The range of n is constrained to lie between 2 and 10. The radius, R, at any altitude z between z_T and z_B, the respective altitudes of the wafer top and bottom, is computed by the geometric interpolation formula

$$R = R_B \left[\left(\frac{R_T}{R_B} \right)^{\left(\frac{z - z_B}{z_T - z_B} \right)} \right] . \tag{2.17}$$

Each of the n small volumes is assumed to have the same vertical thickness. It is also assumed that each contains the same amount of particulate mass. Given the above assumptions, it can be shown that the volume of the ith subvolume is given by

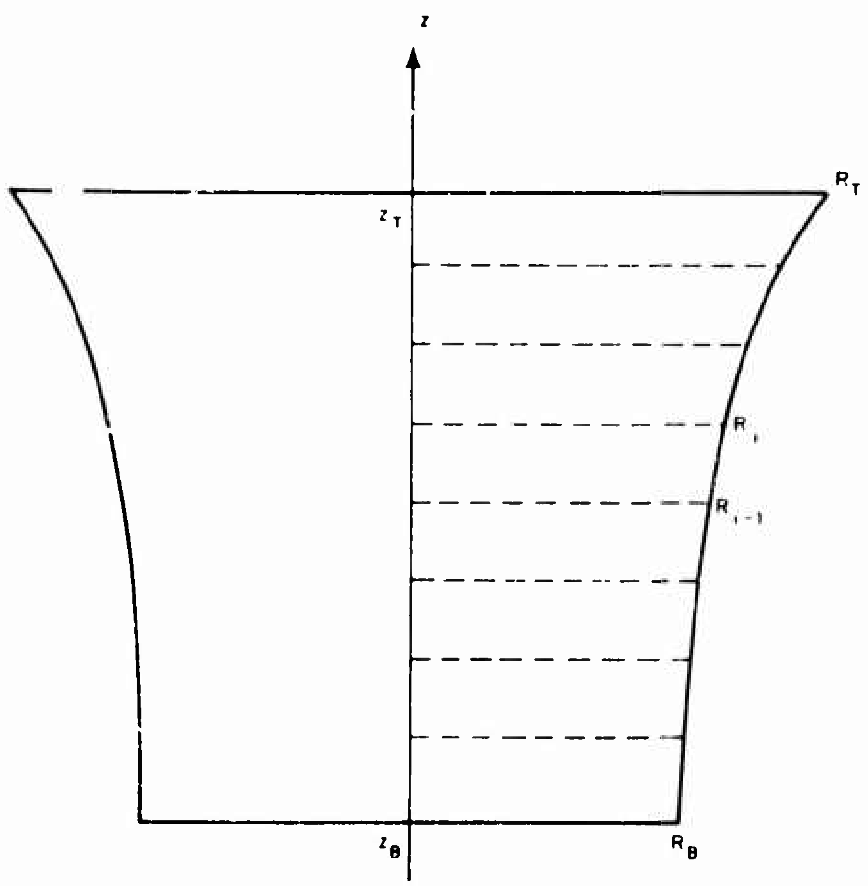


Figure 2.2. Partitioning in the Vertical of a Stem Wafer

$$V_i = \frac{\pi R_B^2 (z_T - z_B)}{2 \ln\left(\frac{R_T}{R_B}\right)} \left[\left(\frac{R_T}{R_B}\right)^{2\left(\frac{z_i - z_B}{z_T - z_B}\right)} - \left(\frac{R_T}{R_B}\right)^{2\left(\frac{z_{i-1} - z_B}{z_T - z_B}\right)} \right] \qquad (2.18)$$

and that the altitude of the center of mass, z_{cm}, of the ith subvolume is given by

$$z_{cm_i} = z_B + \frac{z_T - z_B}{2 \ln\left(\frac{R_T}{R_B}\right)} \ln\left[0.5 \left\{ \left(\frac{R_T}{R_B}\right)^{\frac{2(z_i - z_B)}{(z_T - z_B)}} + \left(\frac{R_T}{R_B}\right)^{\frac{2(z_{i-1} - z_B)}{(z_T - z_B)}} \right\} \right] . \qquad (2.19)$$

The radius of each subvolume is then taken to be the radius at the altitude of its center of mass. In the Cloud Rise Module output each subdivision is assigned the geometric mean particle diameter for its particle size class.

Wafer Velocity Calculation

The velocity of a wafer top or bottom is the difference between the still air particle settling speed and an upward speed to be described below. The settling speed is computed from Davies' equations,[2.4] which require particle diameter, particle density, fluid density, and fluid viscosity (see DASA-1800-IV). For in-cloud settling, cloud gas density is taken from the CX

array and viscosity is calculated from the cloud temperature (also taken from the CX array) by the Sutherland equation (equation (2.23)). For below-cloud settling, temperature and viscosity are taken from the tabulated atmosphere according to the wafer altitude.

The upward velocity component, u_u, is calculated as follows:

1. In-cloud

$$u_u = u_B + (z - z_B)\left(\frac{u_T - u_B}{z_T - z_B}\right) . \tag{2.20}$$

2. Below-cloud

$$u_u = u_B\left(1 - \frac{z_B - z}{z_B - z_{GZ}}\right) . \tag{2.21}$$

u_B and u_T are cloud cap base and top rates respectively, z_B and z_T are cloud cap base and top altitudes respectively, z is wafer top or bottom altitude, and z_{GZ} is ground zero altitude. Values for all cloud properties are taken from the CX array for the appropriate time.

Cloud Wafer Subdivision in the Horizontal

As was discussed in connection with Figure 2.1, the cylindrical cloud. at the initial time, is subdivided in such a manner that it can be considered to be a stack of cylindrical discs, or wafers as we have called them. Initially, the cloud is assumed to have a uniform distribution of soil and each disc actually represents N separate wafers where N is the number of particle size classes. At the end of the RSXP cloud rise calculations, these wafers are distributed between ground zero and the final cloud top height as a result of their gravity settling, and, in general, they will not all have the same radii. (See the discussions of cloud structure and wafer velocity calculation above.)

If these wafers are to be transported through the atmosphere down

wind of the burst location through a horizontally invariant wind field (e.g., a wind field constructed from a single wind hodograph), the wafers, as described above, are completely adequate for input to the transport calculations. On the other hand, if the wind field has horizontal shear which is resolved at distances comparable to, or smaller than, the cloud diameter, the distorting effect of this shear on the cloud cannot be accounted for by a computationally feasible process unless the wafers are subdivided horizontally.

To specify the amount of horizontal subdividing to be done, if any, the user specifies an integer IRAD. If IRAD = 0, no horizontal subdividing is done, and each cloud subdivision is defined in the output with the radius that is determined as described previously. If IRAD > 0 then the cloud wafers and wafer subdivisions are subdivided in the horizontal so that each subdivision has a diameter, BZ, equal to

$$BZ = R_{max}/IRAD \quad , \tag{2.22}$$

where R_{max} is the final (i.e., maximum) cloud radius. The manner in which a wafer is partitioned into subdivisions is illustrated for IRAD = 3 for a wafer of maximum size in Figure 2.3. From the figure we see that specification of IRAD = 3 results in creation of 32 subdivisions from one large wafer. For other values of IRAD we have:

IRAD	No. of Subdivisions from a Wafer of Max. Radius
1	4
2	12
3	32
4	52
5	80

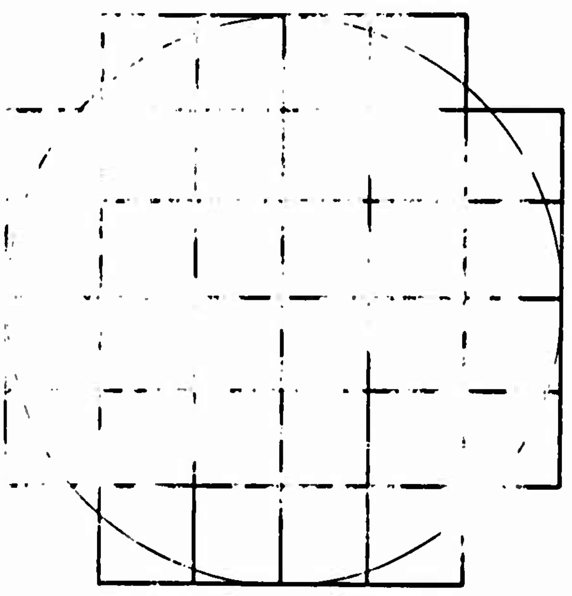


Figure 2.3. Partition of a Wafer in the Horizontal Plane for IRAD = 3.

As shown in the Figure, the partitioning is done as though each subdivision were to be square based; actually, once the subdividing is accomplished, each subdivision is treated as a circular based cylinder with radius BZ/2.0.

From observation of Figure 2.3, it is apparent that portions of some subdivisions extend beyond the boundary of the original wafer. Therefore, a criterion must be set up by which the computer can decide in a particular case whether or not to define a boundary subdivision. This must be a general criterion since wafer radii can possibly have any values between those of the initial and stabilized clouds. The criterion by which a cloud subdivision on the wafer edge is defined, or is not defined, is that the distance of its center from the center of the wafer be equal to, or less than, the wafer radius. In a case where the centers of all possible subdivisions fall outside the wafer edge, a single subdivision is defined with its center coincident with the wafer center. In this latter case, the subdivision radius is taken to be the one already available instead of BZ/2.0 (i.e., it is treated as though IRAD were set to zero).

If a wafer is partitioned into M subdivisions, then each subdivision receives 1/Mth of the wafer's particle content. The vertical dimensions of all subdivisions of a particular wafer are taken as equal to the vertical dimension of that wafer.

<u>Fallout Parcel Descriptions in the Cloud Rise Module Output</u>

Subroutine RSXP writes the Cloud Rise Module output on storage unit IRISE. The data recorded on the unit for each cloud subdivision are:

1. x-coordinate of subdivision center
2. y-coordinate of subdivision center
3. Time relative to detonation
4. Central particle diameter of the particle size class
5. Mass of soil material in the subdivision
6. Altitude of subdivision center of mass above msl

7. Radius of subdivision at its center of mass
8. Vertical thickness of subdivision
9. Altitude of the base of the subdivision above msl
10. Volume of subdivision

All data are in mks units.

It should be noted that for a stem wafer, the volume of the subdivision is computed via equation (2.18) which takes into account a curvature in the wall of the wafer (see Figure 2.2). Therefore the volume specified by item 10 above will not be the same as the volume computed from the radius (item 7) and the vertical thickness (item 8) if the subdivision is assumed to be a right circular cylinder. Moreover, if a wafer has been subdivided in the horizontal, the volume supplied by item 10 is simply the wafer volume divided by the number of horizontal subdivisions that are created. Again, this will not correspond to the volume computed for a right circular cylindrical shaped subdivision.

PROGRAM DESCRIPTION

GENERAL

The Cloud Rise Module computer program has been constructed in a highly modular fashion so that alterations to the program can be made with relative ease and efficiency. The subroutine breakdown of the program can be considered at two hierarchical levels. Subroutines in the upper echelon are the subroutines called by the Cloud Rise Module executive program, subroutine LINK2. These subroutines are ICRD, CRM, and RSXP. In general, the upper echelon programs call one or more additional subroutines and these additional subroutines comprise the lower echelon of programs. Table 2.1 presents a complete list of the Cloud Rise Module subroutines with a brief description of the function of each. Figure 2.4 shows the calling sequence organization.

In the sections to follow, LINK2 and each of the upper echelon programs called by it will be described in detail. Only a brief description of many of

the lower echelon programs will be given because their functions usually are quite narrow, often they are quite short, and the FORTRAN listings provide adequate description. One subroutine, ERROR, is described in DASA-1800-VIII.

Communication between the Cloud Rise Module and other DELFIC modules is accomplished via COMMON and peripherial storage. All inputs from the Initial Condition Module are via COMMON/SET 1/ (see the LINK2 FORTRAN listing) and communication with the Cloud Rise-Transport Interface Module is via both COMMON/SET1/and a pheripherial storage unit (IRISE) written by subroutine RSXP.

SUBROUTINE LINK2 (FC-2.1)

LINK2 is the Cloud Rise Module executive program. There are no major loops in the program and for each cloud rise calculation there is but one pass through it. This simple program needs no explanation beyond that supplied by flow chart FC-2.1.

TABLE ..1

SYNOPSIS OF CLOUD RISE MODULE SUBROUTINES

Subroutine	Called By	Function	FORTRAN Listing On Page
ATMR	ICRD	Reads atmosphere data and prepares a table of atmospheric properties as a function of altitude.	104
CPFR	CRM	Computes rate of fallout of soil material during the cloud rise and adjusts the in-cloud particle-size-number-frequency distribution table accordingly.	109
CPV	CRM	Initializes for the CRM calculations.	111
CRM	LINK2	Cloud rise calculation executive program.	113

TABLE 2.1 (Cont'd.)
SYNOPSIS OF CLOUD RISE MODULE SUBROUTINES

Subroutine	Called By	Function	FORTRAN Listing On Page
CRMW	CRM	Prints the results of the CRM calculations in the form of the CX array.	115
CXPN	CRM	Compiles the CX array and terminates the cloud rise via the MCX or R RATE switch (see pp. 48 ff.).	117
DBG	CRM	Prints the CRM debug output if the control parameter KCLD is given an input value of 1.	119
DCSN	CRM	Changes the time step interval (see p. 47) and terminates the cloud rise calculation via the TEMP, ZLMT, or R.LT.1 switch (see pp. 48 ff.).	121
DERIV	RKGILL	Calculates time derivatives for the variable cloud properties that are simulated by the Cloud Rise Module.	123
ICRD	LINK2	Reads input data for the Cloud Rise Module calculations.	127
LINK2		Cloud Rise Module executive program.	98
PAM	LINK2	Particle activity dummy subroutine.	—
RKGILL	CRM	Performs numerical integration of the cloud rise differential equations.	130
RSTR	CRM	Provides temporary storage for cloud parameters.	132
RSXP	LINK2	Computes particle inputs for the Cloud Rise-Transport Interface Module.	134
TRPL		General utility table look-up and interpolation program.	142

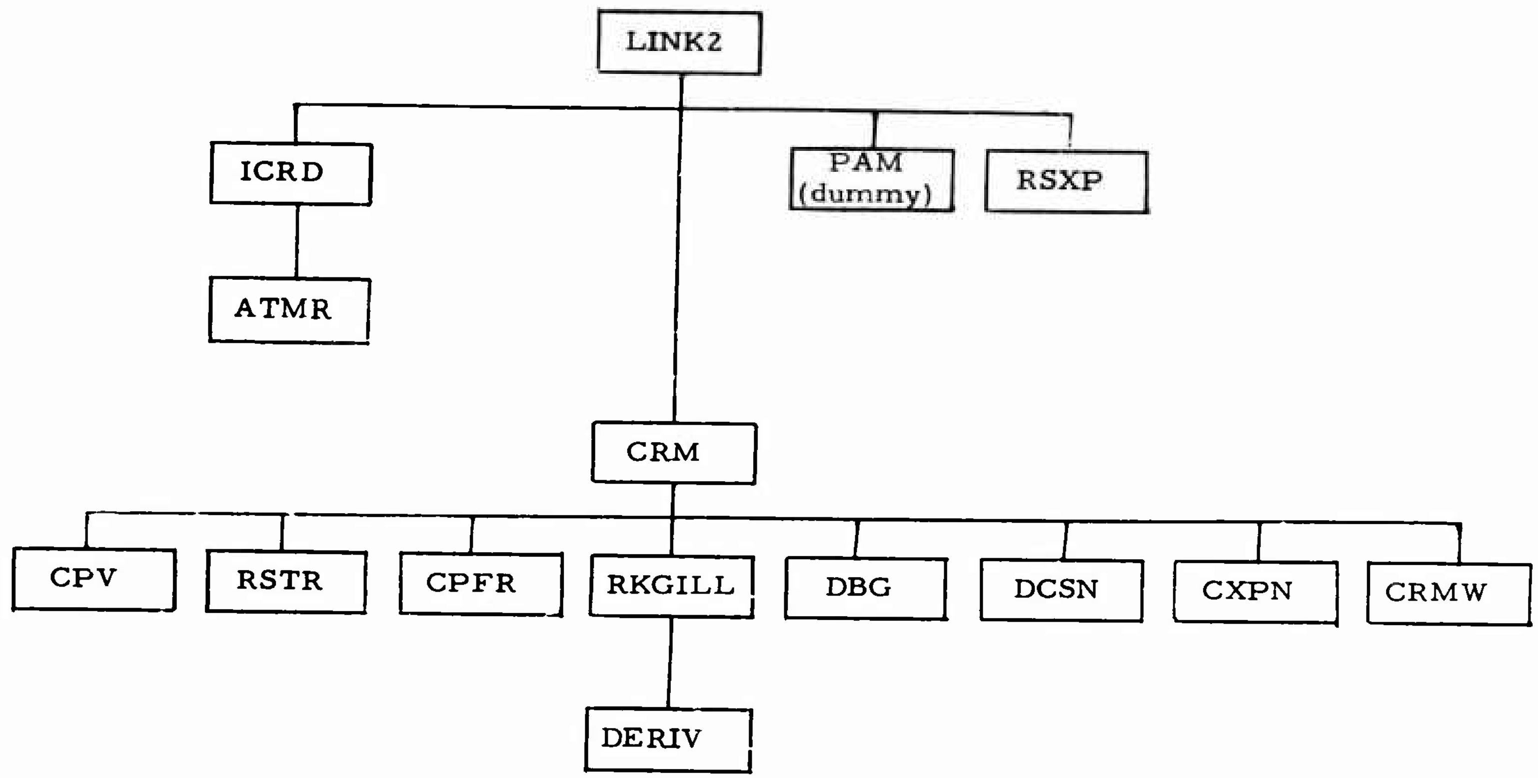
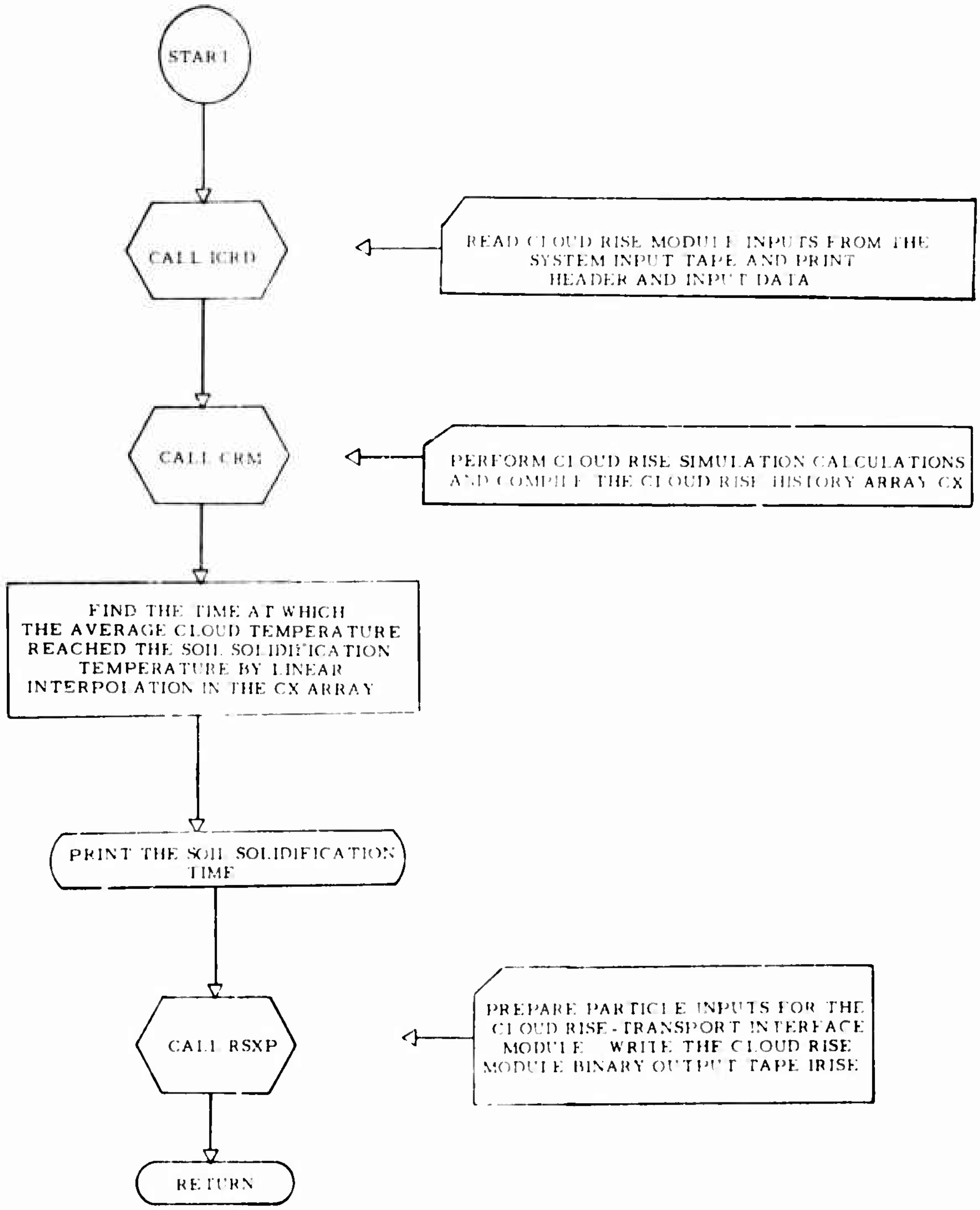


Figure 2.4. Subroutine Calling Sequence Organization for the Cloud Rise Module.



FC-2.1. Subroutine LINK2

SUBROUTINE ICRD (no flow chart)

Subroutine ICRD reads all of the Cloud Rise Module card input data; it prints the header for the Cloud Rise Module, and it prints the input data. Except for the data received from COMMON/SET 1/, all inputs are from the operating system input tape.

One subroutine, ATMR (FC-2.2), is called which reads the atmosphere input data. It is designed to provide the utmost in flexibility of input. The Cloud Rise Module requires that the tables range from -1000 through 50,000 m (above mean sea level) in increments of 200 m. There are 256 altitude levels in the tables. The Cloud Rise Module requires tables of the following atmospheric properties: altitude (m above msl), temperature ($^\circ$K), pressure (mb), density (kg/m^3), relative humidity (%), and viscosity (kg/(m-sec)). Acceleration of gravity (m/sec^2) and molecular mean free path of air (m) also are included in these tables. Only density and viscosity are transmitted to the Cloud Rise-Transport Interface Module.

The only restrictions on the input data are that: (1) altitude, temperature, relative humidity, and either pressure or density must be specified in the input for each input altitude level; (2) the altitude levels should lie between -1000 and 50,000 m; (3) the data for each altitude level must be read in together in a sequence and according to a format common to all levels; and (4) the altitude levels must be input in order of increasing altitude. The data input format is specified by an object-time FORMAT. A card with ten scale-transformation parameters is read so that the data can be provided in any units that happen to be convenient. Ordering of data within altitude levels is arbitrary and is specified by a data sequence card.

Of the eight quantities required, only the four essential quantities listed above must be supplied by input, but any or all of the other quantities can be supplied also. Those not supplied in the input are specified by the program. Viscosity, η (kg/(n -sec)), is computed by Sutherland's equation

$$\eta = \frac{145.8 \times 10^{-8} T^{3/2}}{110.4 + T} \quad , \qquad (2.23)$$

mean free path, M(m), is computed from the expression[2.5]

$$M = 2.33239 \times 10^{-7} \; T/P \quad , \qquad (2.24)$$

where T is temperature in degrees Kelvin and P is pressure in millibars, the acceleration of gravity is assigned a constant value of 9.8 m/sec^2, and pressure or density is calculated by the expressions

$$P = 2867.9 \rho T + P_W H_R \left(1 - \frac{18}{29}\right) / 100 \qquad (2.25)$$

or

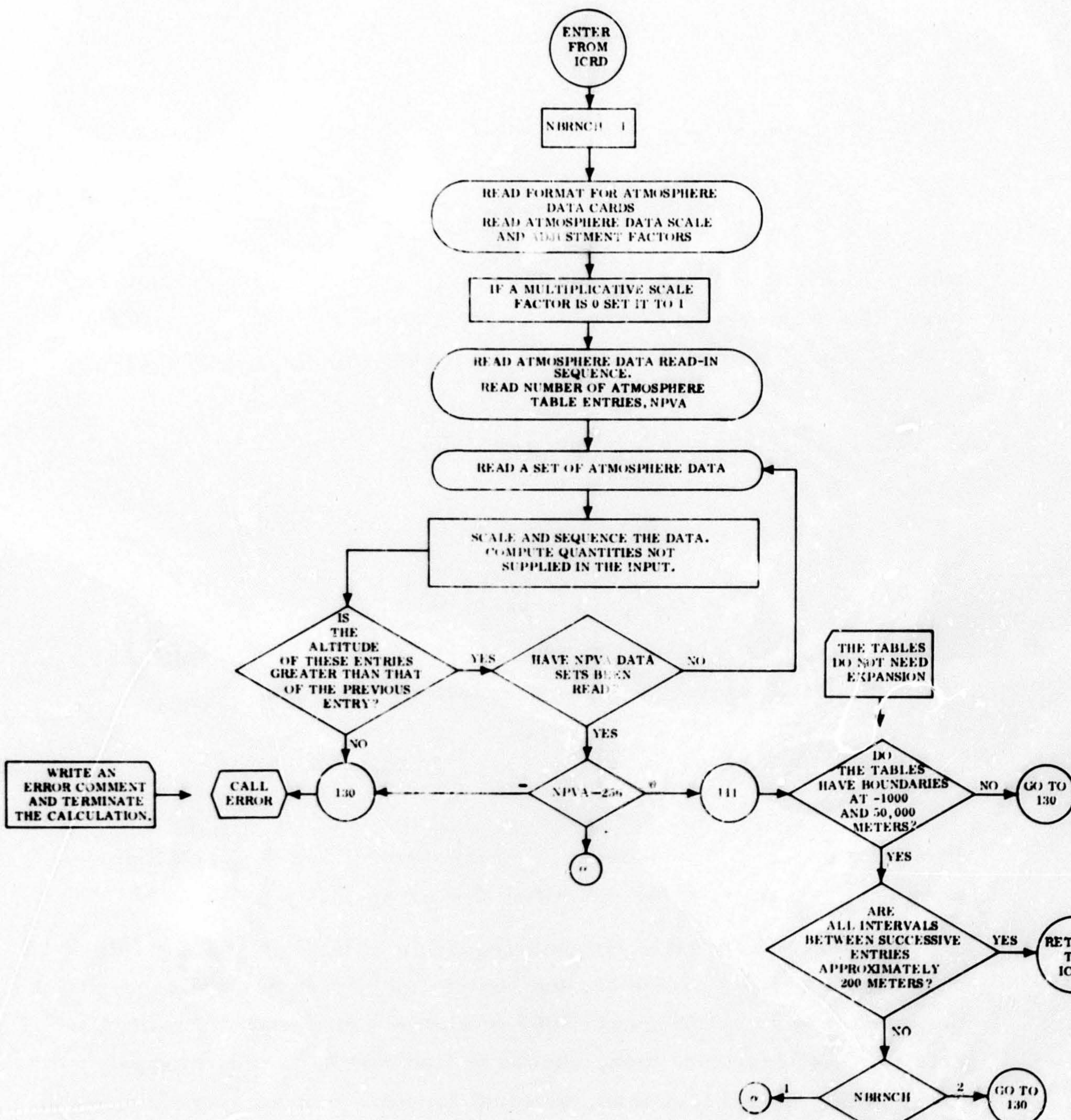
$$\rho = \left[P - P_W H_R \left(1 - \frac{18}{29}\right) / 100\right] / (2.8679 \; T) \qquad (2.26)$$

where P_W, the saturation vapor pressure of water, is

$$P_W = 6.11 \left(\frac{273}{T}\right)^{5.13} \exp\left[\frac{25(T - 273)}{T}\right] \quad . \qquad (2.27)$$

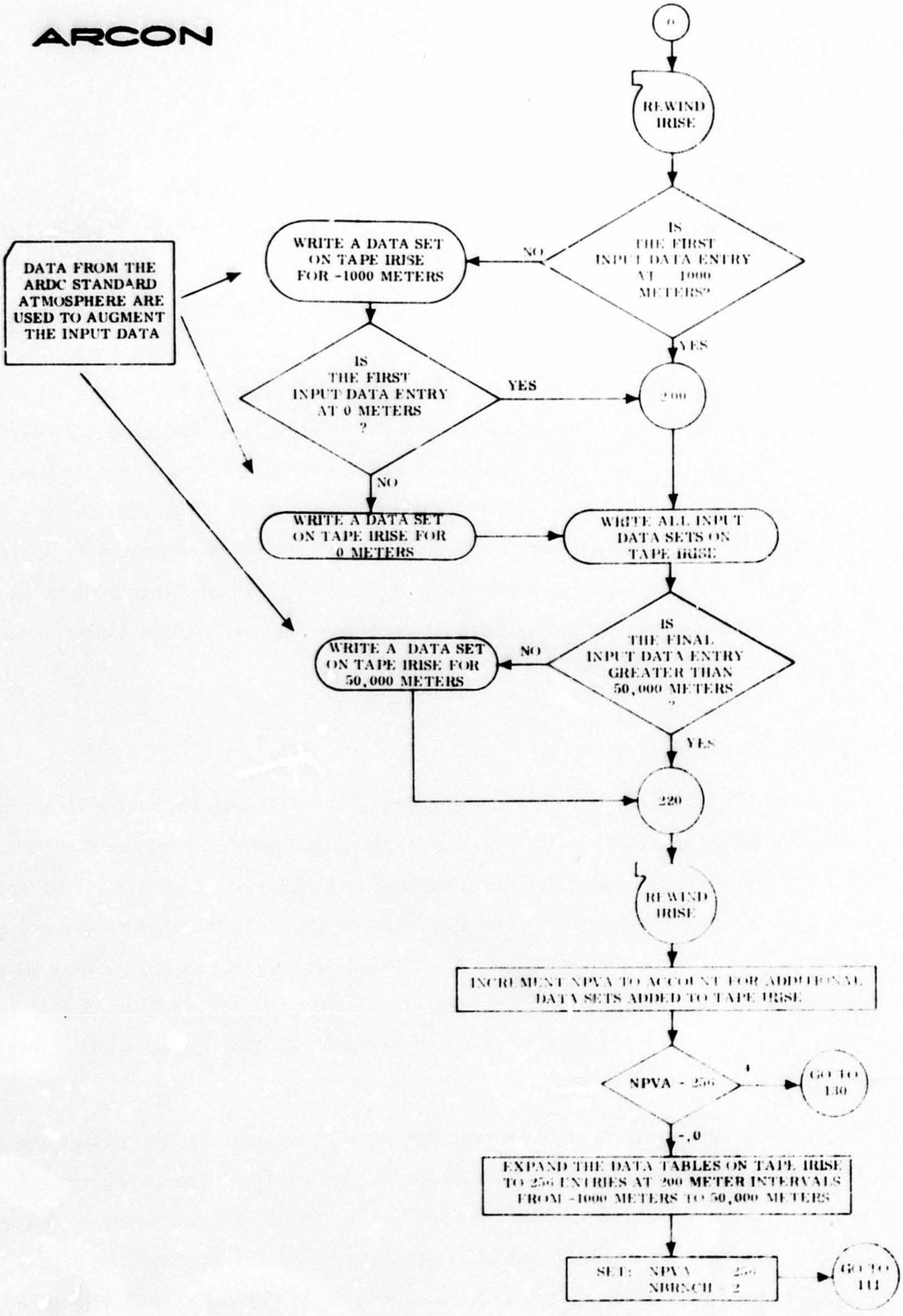
P is total pressure; ρ, density; T, temperature; and H_R, relative humidity. Units for these quantities are as specified previously.

The input is unrestricted with regard to altitude levels and intervals between levels except for the restrictions already mentioned. If the input data do not begin at -1000 m altitude, the program provides data for this level and, then, checks to find whether the first input entry is for a level less than, or equal to, zero meters altitude. If not, data for zero meters altitude also is provided. Finally, if the last input entry is for an altitude level below 50,000 m, data for 50,000 m altitude is added by the program. The added data are taken from the ARDC Model Atmosphere tables (reference 2.5). Entries for all other altitudes



(a)

FC-2.2. Subroutine ATMR



(b)

FC-2.2. (Cont'd.) Subroutine ATMR

are determined by linear interpolation from the composite input and Model Atmosphere tables.

If an input table is encountered with 256 entries, the program checks (after scaling) to determine whether the first and last entries are at -1000 and 50,000 m. If they are not, an error indication is printed and the run is terminated. If the table boundaries are satisfactory, the program then checks to determine whether the altitude entries are at intervals of 200 m. If they are not, table entries are determined by interpolation as for other tables. For all tables, each altitude entry is checked as it is read to determine if it is for a level above that of the previous entry. If not, an error indication is printed and the run is terminated. Peripheral storage unit IRISE is used for temporary storage if the input data deck must be expanded. Additional details are presented in the User Information section.

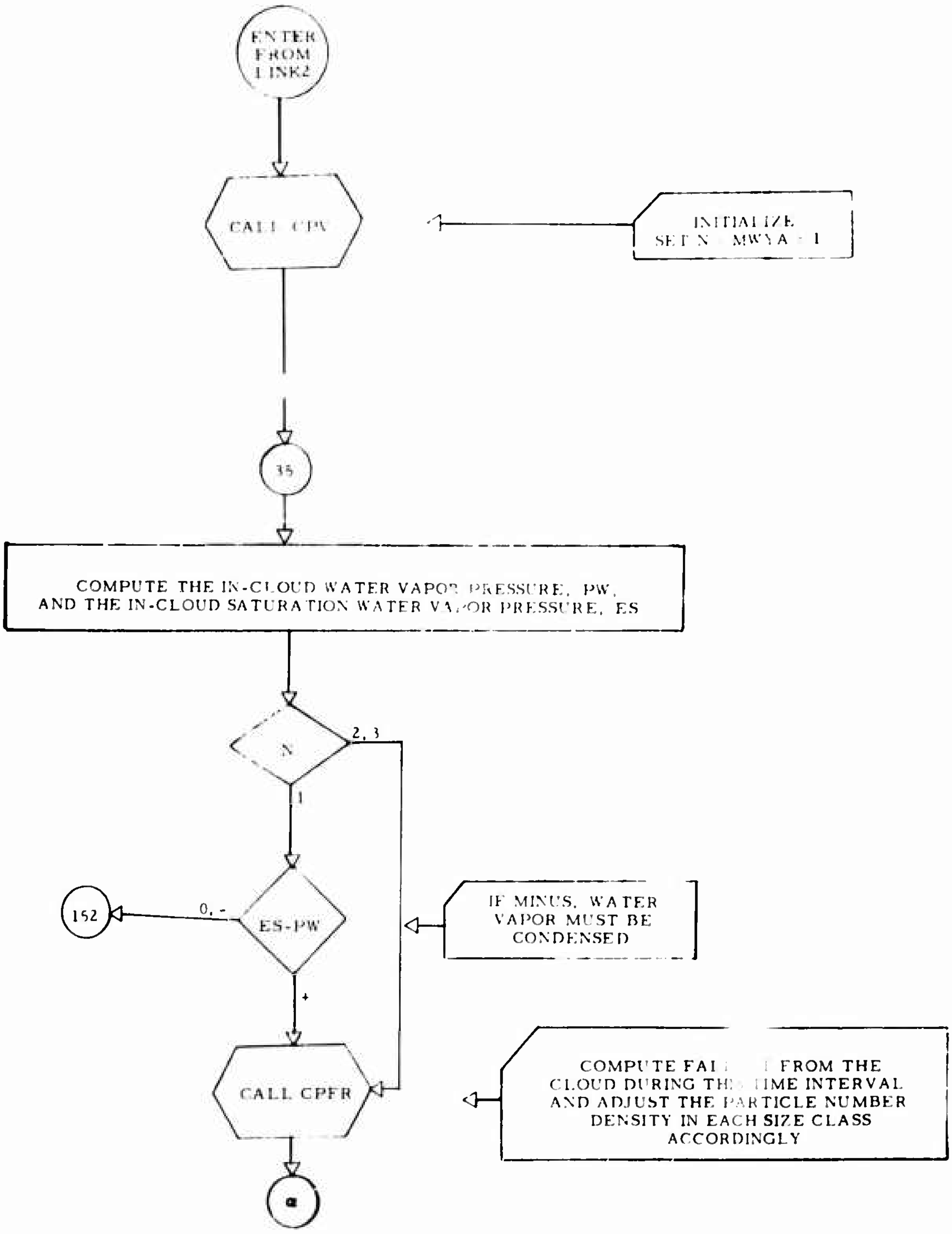
SUBROUTINE CRM (FC-2.3)

Subroutine CRM is the executive program for performing the cloud rise simulations according to the mathematical models described in Part 1. On entrance from LINK2, the program initializes via a call to subroutine CPV. In CPV, initial values of certain computation control parameters are set and initial values of various parameters used in computing the differential equations are computed. After initialization, CRM prints the fraction of the total explosion energy yield in the cloud at the beginning of the cloud rise.

The calculation then enters the iterative portion of the program where the cloud rise and expansion are computed by numerical integration of the basic differential equations over successive small time steps. Computation flow is shown in FC-2.3 which, in conjunction with the discussion of control parameters below, provides an ample description of the program.

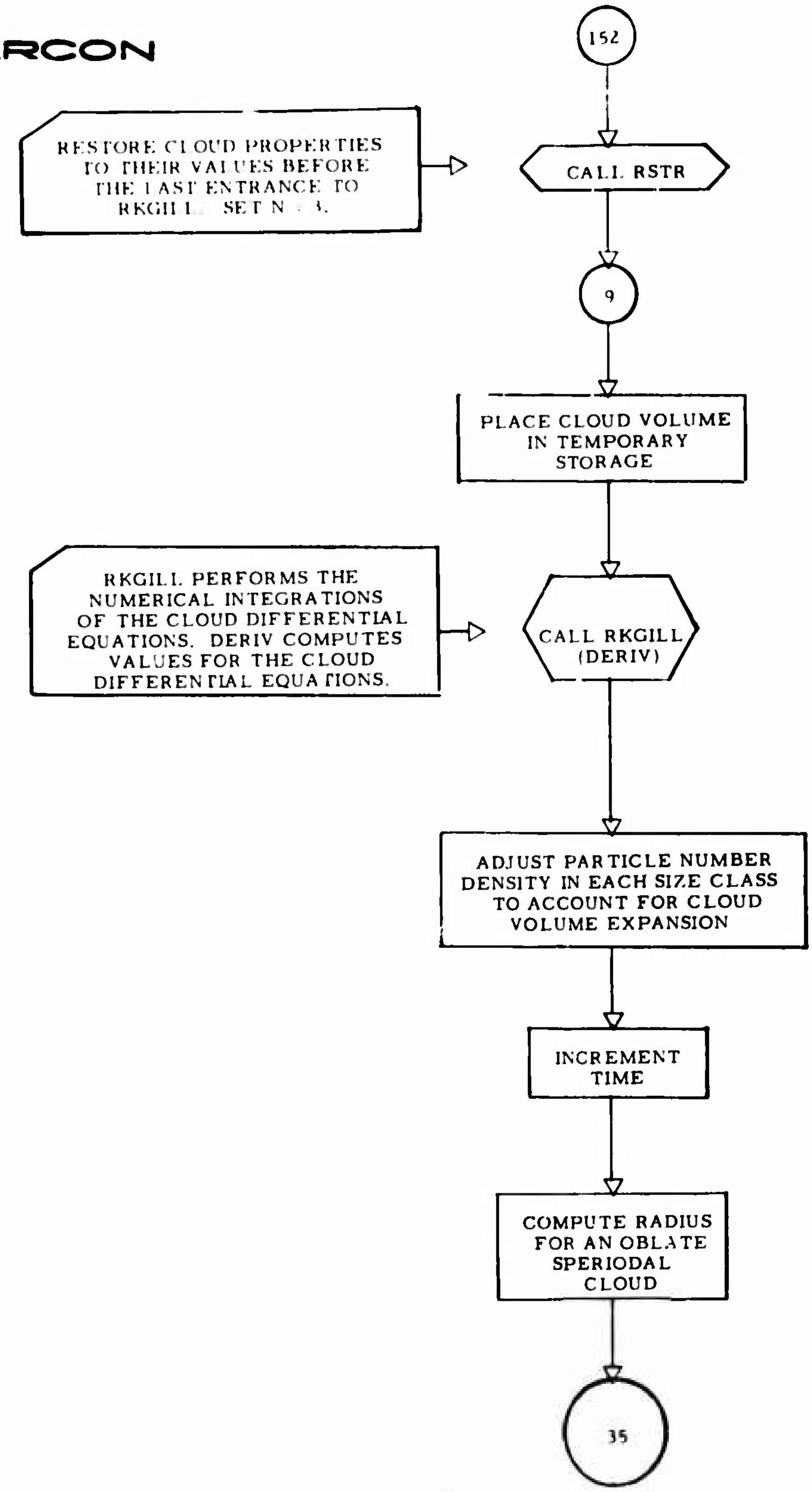
Routing through the program is rather complex and is determined by a number of control parameters. These are N, MWYA and KCLD. Their functions are as follows:

ARCON



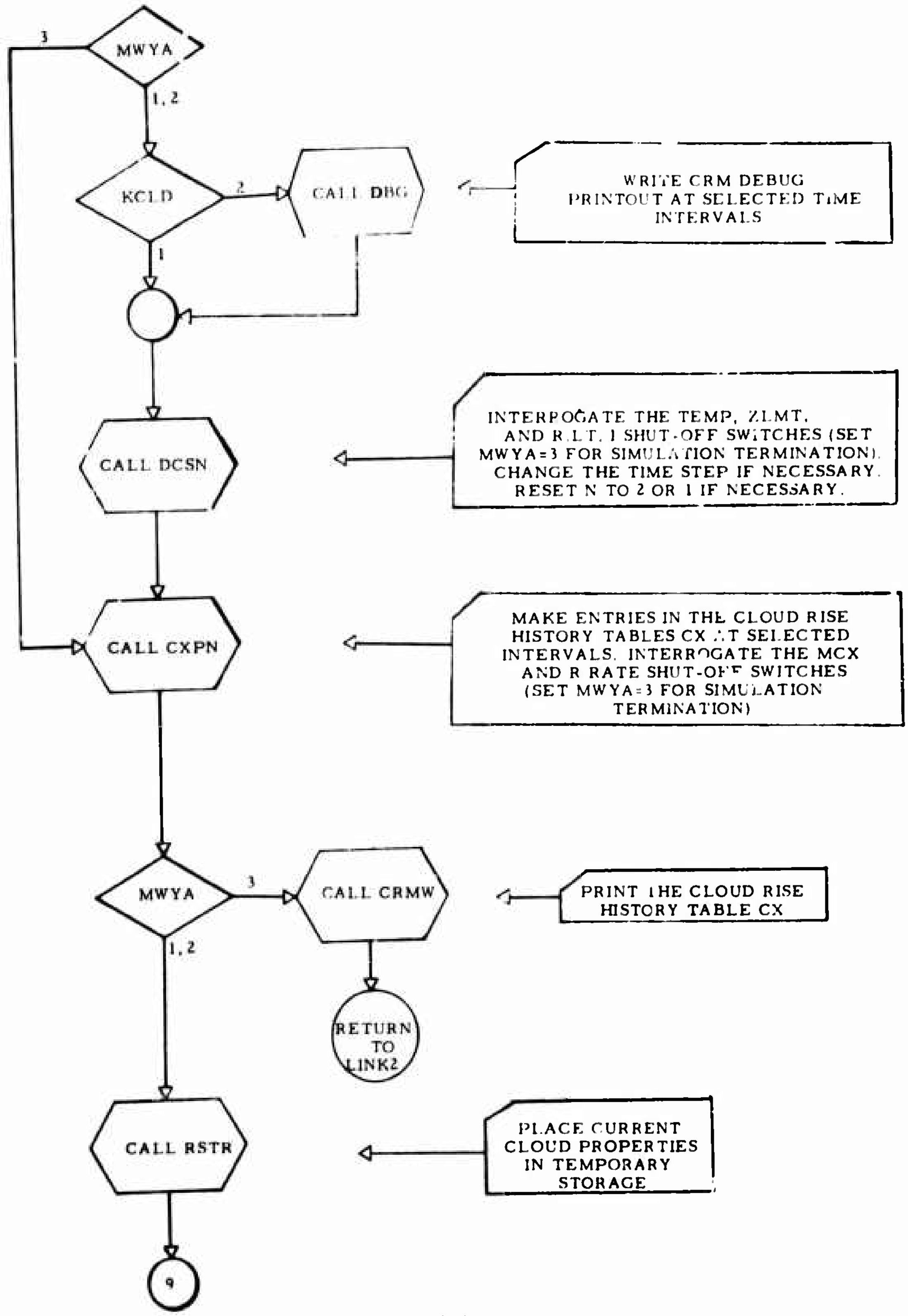
(a)

FC-2.3. Subroutine CRM



(b)

FC-2.3 (Cont'd.) Subroutine CRM



(c)

FC-2. 3. (Cont'd.) Subroutine CRM

N - This parameter determines whether the "wet" or "dry" mode is to be used in calculating the differential equations (see Part 1) in subroutine DERIV. N is given an initial value of 1 in CPV On a normal pass through the iterative portion of CRM, control passes through subroutine RSTR, where current values of cloud properties are placed in temporary storage, and on to RKGILL, which calls DERIV (in which the derivatives are calculated), and then performs the integrations. In DERIV, the "dry" equations are calculated when N is 1 or 3, and the "wet" equations are calculated when N = 2. In CRM after exit from RKGILL, the water vapor pressure in the cloud, PW, and the saturation vapor pressure of water at the cloud temperature, ES, are calculated. If N = 1, PW is checked against ES (if N is 2 or 3, this check is bypassed) and if PW is found to be less than, or equal to, ES, N is left unchanged everywhere and computation follows normal routing. If PW is greater than ES, a special entrance is made to RSTR in which the cloud property values are restored to their values before the last entrance to RKGILL and N is set to 3. On exit from RSTR, control is immediately transferred back to RKGILL where the differential equation calculations and integrations again are computed using the "dry" equations. When N has a value of 2 or 3, the computations of PW and ES in CRM are carried out as before, but the test of PW against ES is bypassed and by means of the normal routing procedure control eventually passes to subroutine DCSN. In DCSN whenever the conditions N = 3 and PW > ES are encountered, N is set to 2. Control then follows normal routing back to RSTR for storage of current cloud properties and then into RKGILL. Now, however, since N = 2, subroutine DERIV calculates the "wet" differential equations. In CRM new values for PW and ES are

computed and control passes on to DCSN. Now, with N = 2, DCSN checks PW against ES and if PW < ES, N is set back to 1. Otherwise, it is left alone and computation with the "wet" equations continues.

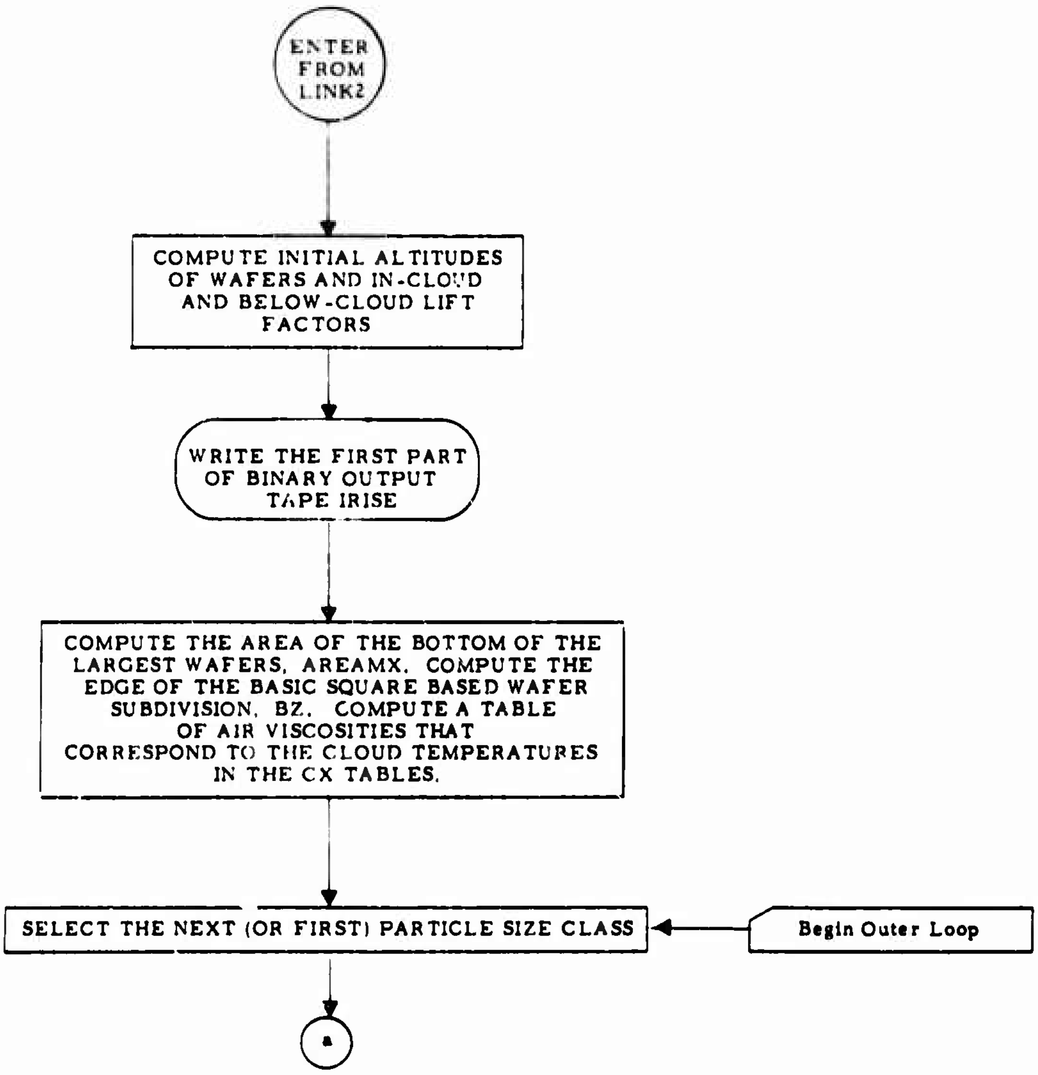
MWYA - An initial value of 1 is assigned to MWYA in CPV. This value is used to signal the first pass through subroutine CXPN, which on the first pass initializes for the construction of the cloud rise history tables, CX, and for the R RATE shutoff switch (see p. 49). After this initialization, CXPN sets MWYA to 2 and this value is maintained until one of the six cloud rise shutoff switches (in subroutines CXPN, DCSN, and CPFR) is thrown. Then MWYA is given the value 3, and this value causes the cloud rise calculations to terminate via transfer to subroutine CRMW which prints the CX tables.

KCLD - This is the CRM debug printout control parameter. An input value of 0 for KCLD causes the CRM debug printouts to be bypassed. An input value of 1 results in transfer of control to subroutine DBG on each pass through the iterative portion of CRM. Subroutine DBG prints out extensive tables of intermediate cloud properties at selected intervals during the cloud rise calculations. Also printed (in DCSN) are comments to indicate when the calculations switch to "wet" or to "dry" (see discussion of control parameter N above).

SUBROUTINE RSXP (FC-2.4)

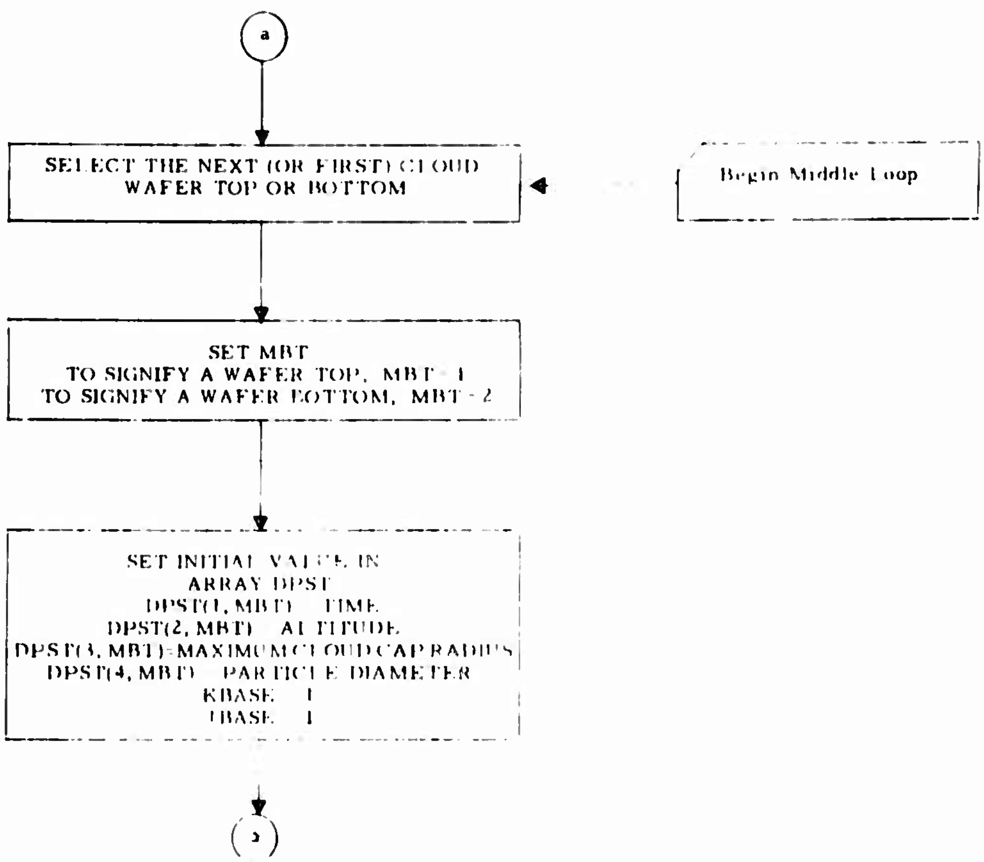
Subroutine RSXP prepares particle inputs for use by the Cloud Rise-Transport Interface Module. The methods and geometric constructs used by this program are discussed in considerable detail beginning on p. 51 and the reader should study those discussions before he attempts to understand the operation of the computer program.

The program begins with an initialization that computes initial altitudes for



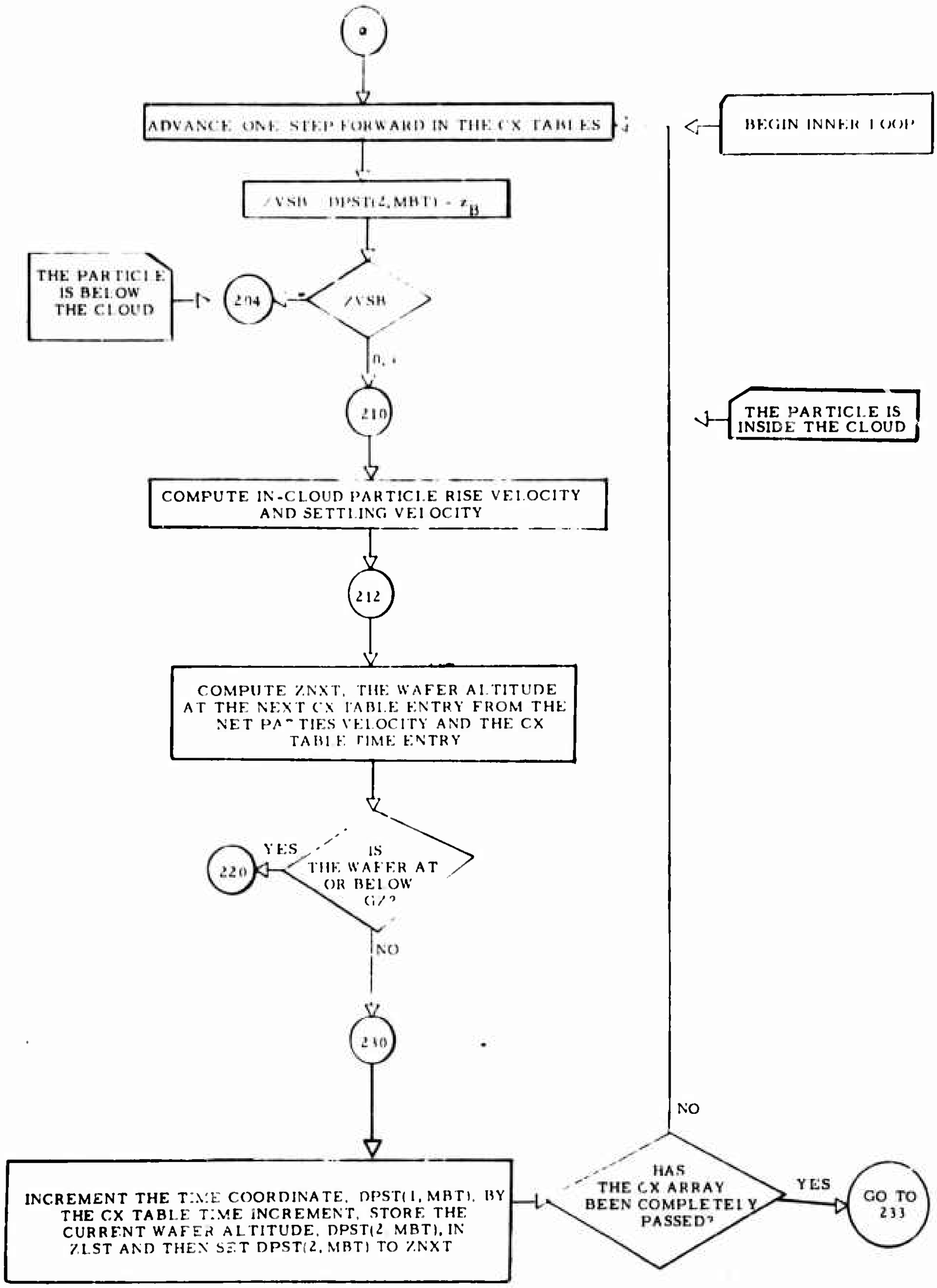
(a)

FC-2.4. Subroutine RSXP



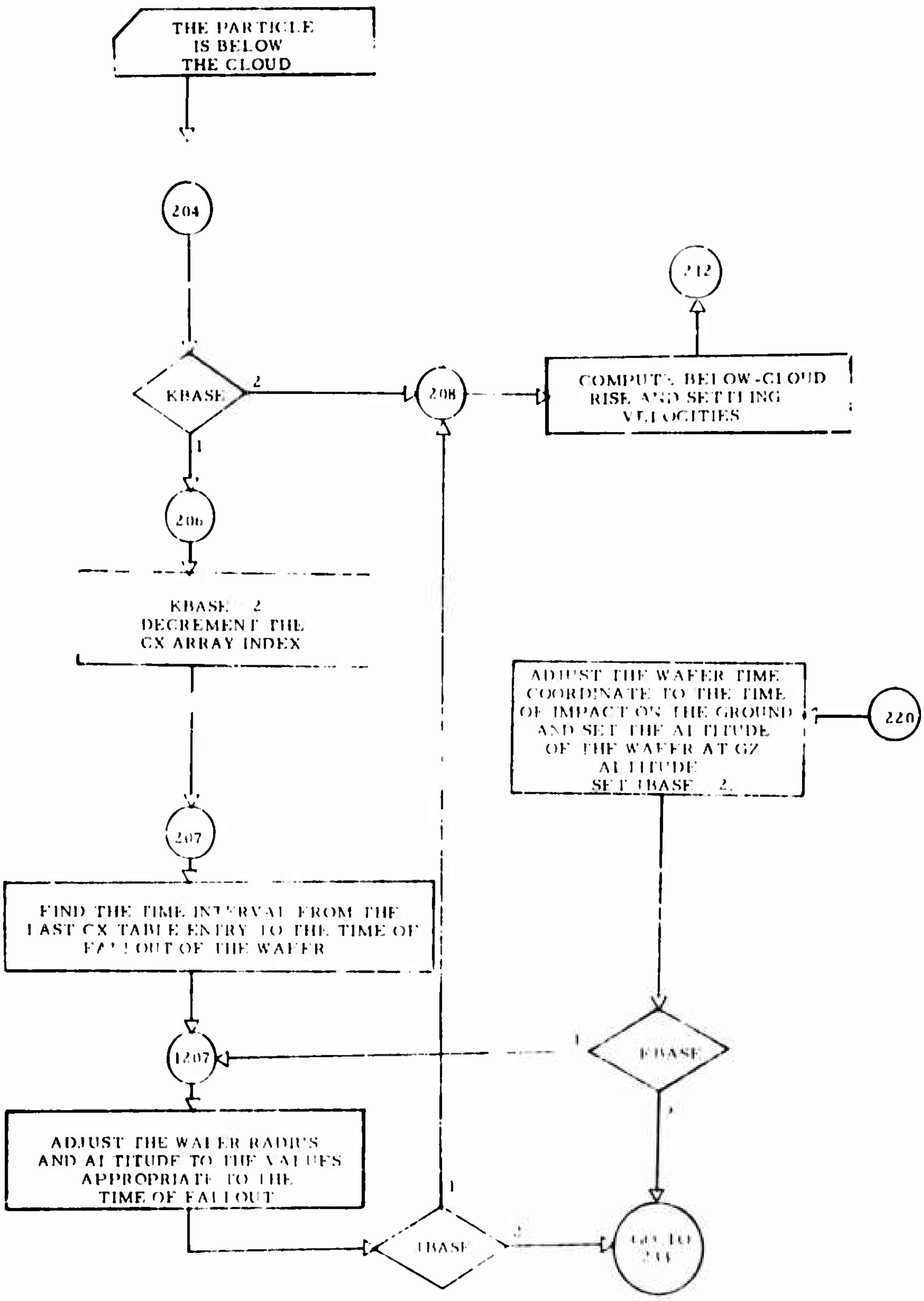
(b)

FC-2.4. (Cont'd.) Subroutine RSXP



(c)

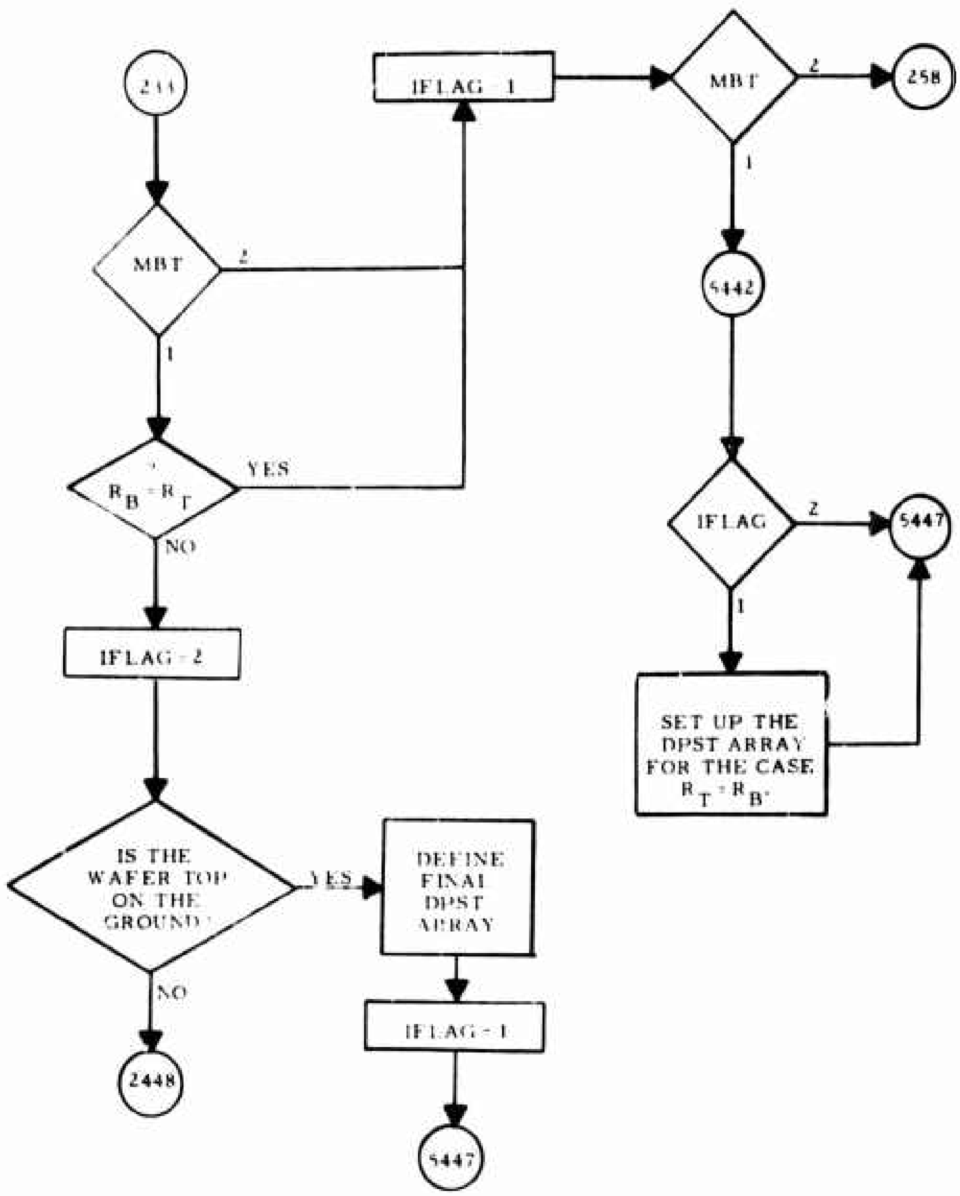
FC-2.4. (Cont'd.) Subroutine RSXP



(d)

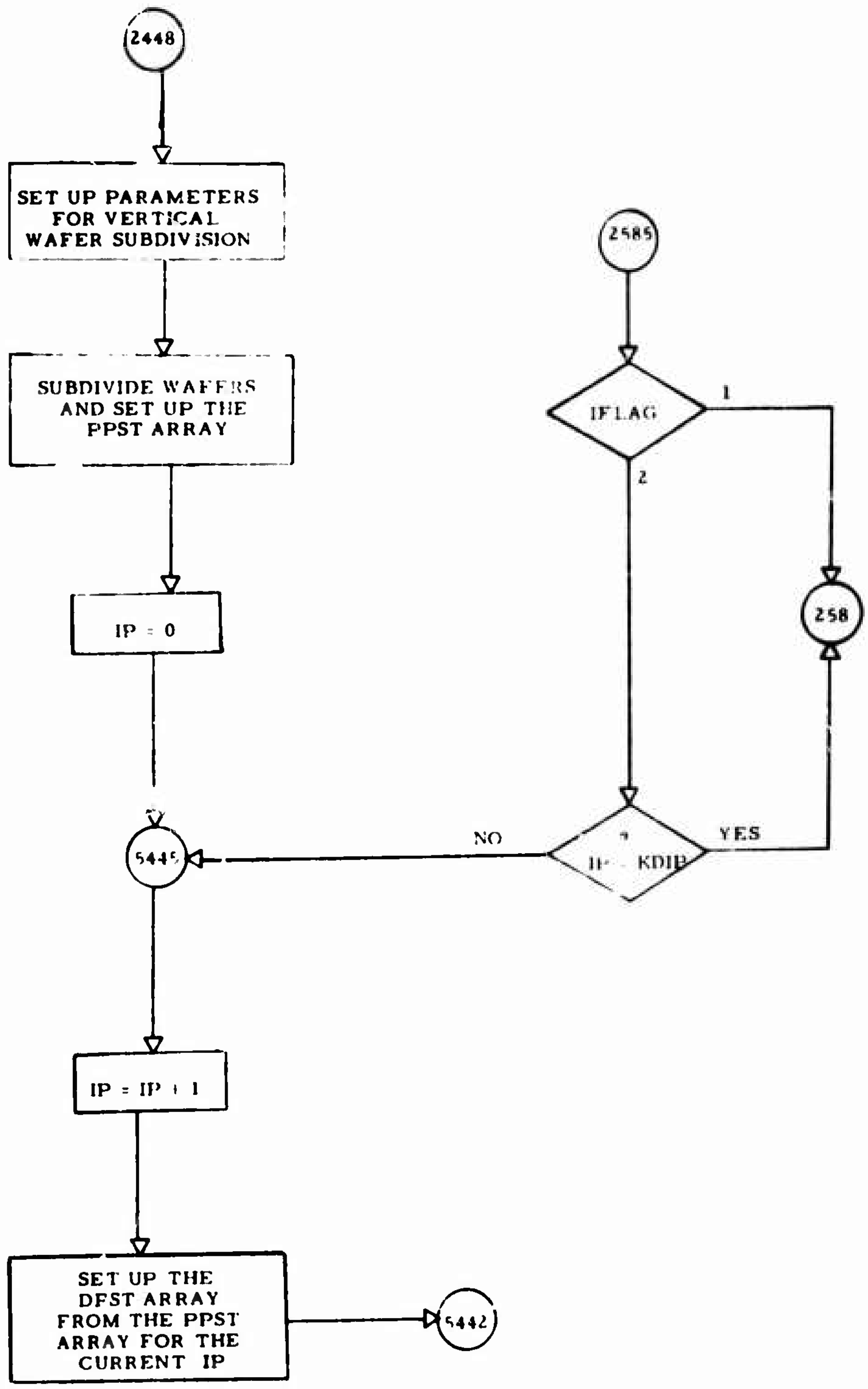
FIG. 2.4 (Cont'd.) Subroutine RSXP

ARCON



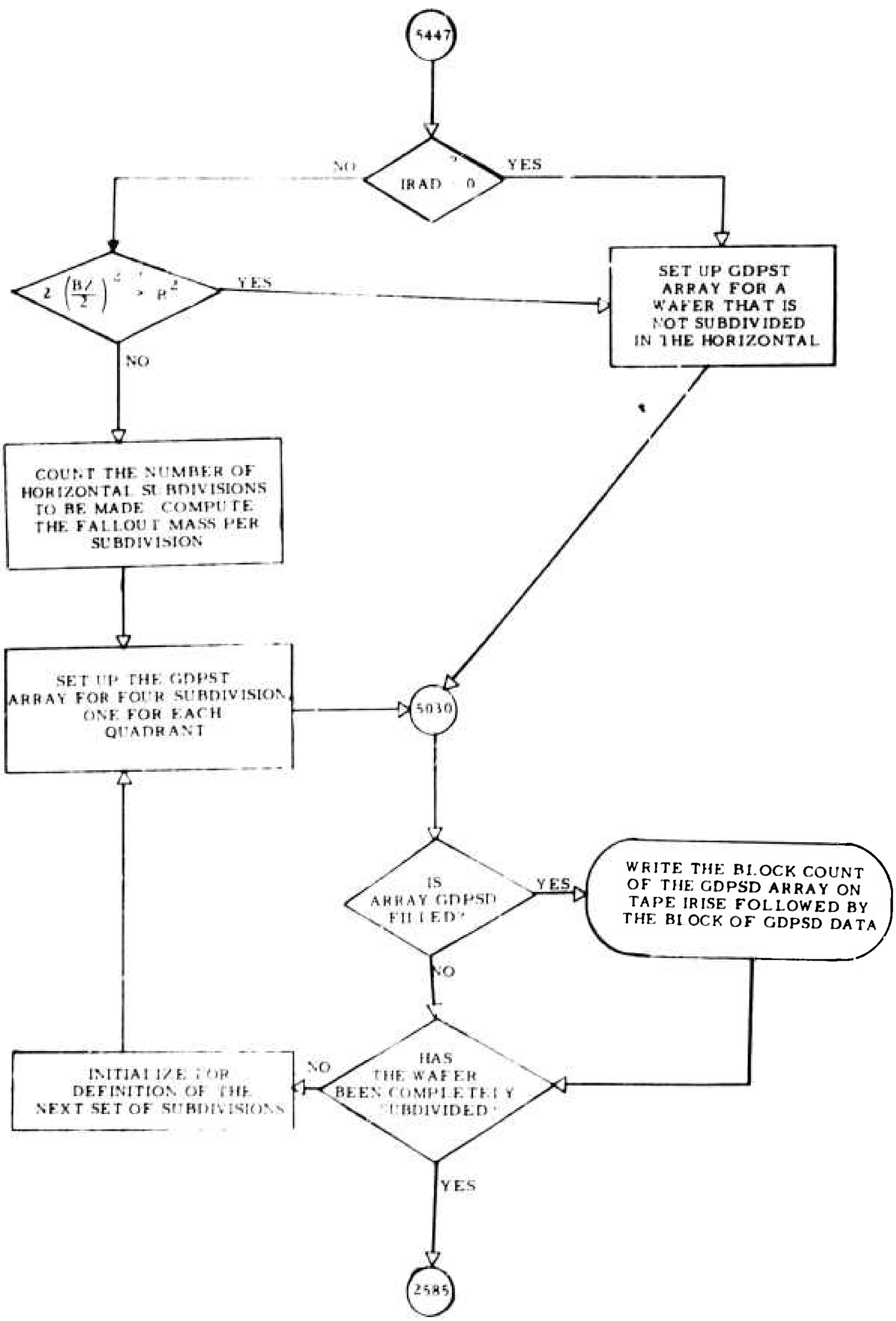
(e)

FC-2.4. (Cont'd.) Subroutine RSXP



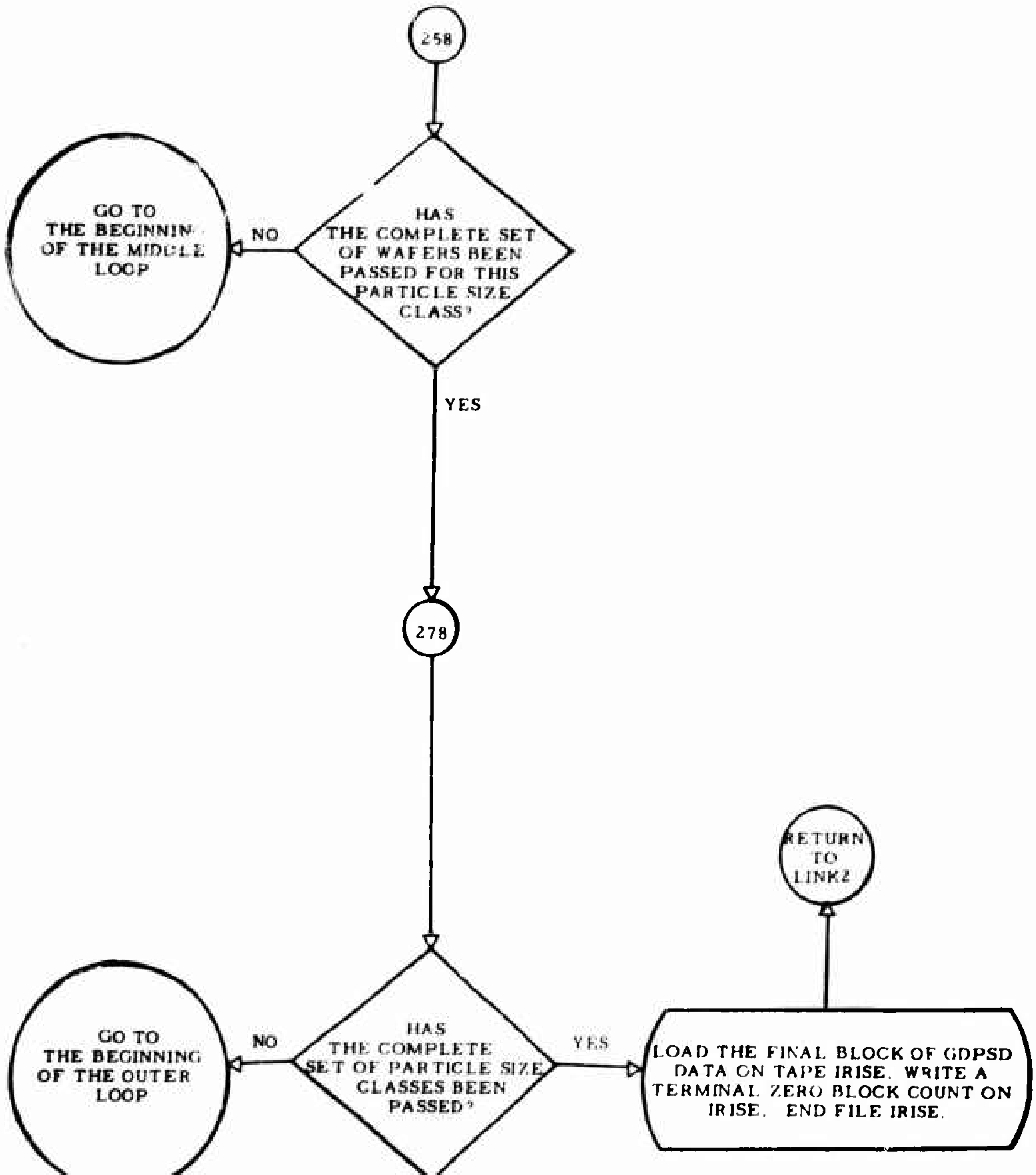
(f)

FC-2.4. (Cont'd.) Subroutine RSXP



(g)

FC-2.4. (Cont'd.) Subroutine RSXF



(h)

FC-2.4. (Cont'd.) Subroutine RSXP

the cloud subdivisions (wafers), array DPSTZ, and the so-called in-cloud and below-cloud lift factors, array DPX, for each time entry in the CX tables. These lift factors are respectively $(u_T - u_B)/(z_T - z_B)$ and $u_B/(z_B - z_{GZ})$, as defined in equations (2.20) and (2.21). The program sections the cloud into KDI wafers for each size class, where KDI is an integer input to subroutine ICRD. If KDI has not been specified, it is given a value as specified on p. 52 . Also the initialization includes: write-out of the header on the Cloud Rise Module output peripherial storage unit IRISE, computation of BZ (see equation (2.22)), and computation of in-cloud air viscosities for each time in the CX table via Sutherland's equation (equation (2.23)).

The main calculations in the program are contained in three nested loops that iterate over the following quantities:

Loop	Iterative Quantity
outer	particle size classes
middle	cloud wafers
inner	the cloud history array CX.

The outer loop simply passes through the particle size class table. At the beginning of the middle loop, a parameter MBT is computed to have a value of 1 or 2 depending on whether a wafer top or bottom (respectively) is being considered. Next, the DPST array, which is for intermediate storage of fallout parcel properties, is initialized in preparation for entering the inner loop.

Inside the inner loop, the cloud rise history array, CX, is passed and at each entry the net vertical motion of the particle is computed and the altitude of the wafer top or bottom is adjusted accordingly. If the wafer top or bottom falls through the bottom of the cloud, its radius is set equal to the cloud cap radius at the time of its fallout. The motion of all wafers is computed for the full time covered by the CX tables with the exception that if a wafer top or bottom reaches ground zero, the calculation is terminated for that wafer part at that time.

The inner loop exits back into the middle loop where the wafer is subdivided further if required. If a wafer top and bottom pair are found to have equal radii, no further subdividing is done in the vertical and control passes to the portion of the code that loads the GDPST array in preparation for the output. If a wafer top and bottom pair are found to have different radii, then the wafer is subdivided further in the vertical as described on pp. 52 ff. An array PPST is used to store the basic wafer data for all vertical subdivisions. Then array DPST is filled from the PPST array for each vertical wafer subdivision in its turn, as control is alternated between this portion of the code and the portion that loads the GDPST array.

At the end of the middle loop is the code that loads the GDPST array. This is the fallout parcel data array from which the output is taken. If the input parameter IRAD is zero, no subdividing of wafers in the horizontal plane is requested. In this case, the parcel data are loaded directly into the GDPST array. If IRAD > 0, a test is made to determine if the wafer radius is less than the diagonal of a square of edge BZ/2. If the test is affirmative, no horizontal subdividing is done and the GDPST array is loaded. If the test is negative, a computation is done to determine the number of horizontal subdivisions that are to be made. Using this number, the wafer mass and volume are apportioned equally among the subdivisions. Next, the subdividing is done and the GDPST array is loaded with the parcel data. Details of the horizontal wafer subdividing are discussed beginning on p. 56. Whenever the array GDPST is filled, it is written on the binary output unit IRISE preceded by the count of parcels in the data block.

When all wafers for a particle size class are treated, the middle loop exits to the outer loop for incrementation of the size class counter; when all size classes are treated, a zero block count is written on unit IRISE followed by an end-of-file, and then control is returned to subroutine LINK2.

USER INFORMATION

GENERAL

The DELFIC system of computer codes has been written to operate on

the UNIVAC 1108 computer under control of either the EXEC-2 or EXEC-8 Monitor Systems. It also is operational on the IBM 360/75 computer.

INPUT DESCRIPTION

Input to the Cloud Rise Module is of two categories:

1. Inputs from LINK1, the Initial Conditions Module (DASA-1800-II and its revisions), and M4, the DELFIC system executive program (DASA-1800-VII and its revisions), via COMMON/SET1/.
2. Card inputs via the operating system input unit.

COMMON/SET1/Inputs

COMMON/SET1/ is defined in the LINK2 FORTRAN listing (see p. 102). Each of the quantities in this set, is described in Table 2.2.

TABLE 2.2

CONTENTS OF THE CLOUD RISE MODULE COMMON/SET 1/

Mnemonic and Dimension	Description	Units	Source
CAY	Coefficient of the frequency function for the power law particle size frequency distribution.		LINK1
DETID(12)	Hollerith identification of the initial conditions calculation.		LINK1
DIAM(201)	Upper boundary of each particle size class. The last entry in the DIAM array is the lower boundary of the last (smallest) particle size class. The length of the DIAM array is always one greater than the number of size classes.	Micrometers	LINK1
DMEAN	Median diameter of a lognormal particle size distribution.	Micrometers	LINK1
DNS	Fallout particle density.	gm/cm^3	LINK1

TABLE 2.2 (Cont'd.)

CONTENTS OF THE CLOUD RISE MODULE COMMON/SET 1/

Mnemonic and Dimension	Description	Units	Source
EXPO	Exponent of the frequency function for the power law particle size frequency distribution.		LINK1
FMASS(200)	Fractions of total particle mass in the particle size classes.		LINK1
IDISTR	Particle size distribution type specification index: 1. lognormal 2. power law 3. arbitrary tabular		LINK1
IEXEC	An index used by the Transport Module (DASA-1800-IV) to control routing by the DELFIC system executive program M4 during transport.		
IRISE	Logical number of the Cloud Rise Module binary output unit.		M4
ISIN	Logical number of the operating system input unit.		M4
ISOUT	Logical number of the operating system output unit.		M4
NDSTR	Number of entries in the particle size-mass frequency array FMASS.		LINK1
PS(200)	Particle size class central particle diameters.	Meters	LINK1
SD	Geometric standard deviation, S, of the lognormal particle-size distribution.	dimensionless	LINK1
SSAM	Mass of condensed phase material in the cloud at the initial time.	kilograms	LINK1

TABLE 2.2 (Cont'd.)

CONTENTS OF THE CLOUD RISE MODULE COMMON/SET 1/

Mnemonic and Dimension	Description	Units	Source
TME	Time relative to burst time of the initial conditions specification.	seconds	LINK1
TMP1	Average temperature of gaseous matter in the cloud at the initial time.	degrees Kelvin	LINK1
TMP2	Average temperature of condensed phase material in the cloud at the initial time.	degrees Kelvin	LINK1
PHI, T2M	Fraction of available energy used to heat air.		ICRD
USOIL	Soil Class Indicator: 1. siliceous 2. calcareous		LINK1
VPR	Mass of vaporized soil material in the cloud at the initial time.	kilograms	LINK1
W	Total energy yield of the explosion.	kilotons equivalent of TNT	LINK1
HEIGHT	Height of burst above ground zero.	meters	LINK1
ZSCL	Scaled height of burst relative to ground zero.	$ft/(kT)^{1/3.4}$	LINK1
NHODO	Number of entries in wind data table.		LINK1
ZV(200)	Altitudes of center planes of the wind strata.	meters	LINK1
VX(200)	X-components of wind velocities in the wind strata.	m/sec	LINK1
VY(200)	Y-components of wind velocities in the wind strata.	m/sec	LINK1

Card Inputs

The card input to the Cloud Rise Module is read by subroutine ICRD and ATMR. Data other than the control parameters and the atmosphere data need no explanation in addition to that provided in Table 2.3. The control and atmosphere data, on the other hand, are given special attention below.

Control Data:

KDI - This is the number of wafer subdivisions for each particle size class (see Figure 2.2). It has no upper limit. If its input value is zero, it is calculated in subroutine RSXP (see p. 51).

IRAD - This is the wafer radius division factor to be used in subdividing the cloud wafers in the horizontal plane. (See Figure 2.3.). It has no upper limit.* If its input value is zero, the cloud is not subdivided horizontally.

KCLD - This controls the CRM debug printout. If the debug printout is requested, a detailed printing of cloud and particle properties is executed at intervals during the CRM calculations (see the discussion of outputs below).

0 debug printout is not requested
1 debug printout is requested

KRX - This controls the RSXP debug printouts. The RSXP debug printout describes each "wafer" (see p. 51-55) output by the RSXP calculations (see the discussion of outputs below).

0 debug printout is not requested
1 debug printout is requested

IPAM - This parameter controls entrance to, or bypass of, subroutine PAM. In this version of DELFIC, PAM is a dummy subroutine and IPAM is always zero.

---

*Careful attention should be given to this parameter. A large value can cause a very large amount of transport computer time to be required. Since almost always winds vary only gradually in the horizontal, and since rarely are there sufficient wind data available to provide fine resolution of the horizontal winds, then it is unlikely that use of a large value of IRAD can be justified.

TABLE 2.3

A SUMMARY OF CARD INPUTS TO THE CLOUD RISE MODULE

Card Number	Contents	Variable Names and FORMAT
1	Cloud Rise Run identification	DNID(J)(12A6)
2	Control indices: KDI – number of wafers per size class IRAD – wafer subdivision factor KCLD – CRM debug print control 0 do not print 1 print KRX – RSXP debug print control 0 do not print 1 print IPAM – always given a value of zero KATM – atmosphere printout control 0 do not print 1 print.	KDI, IRAD, KCLD, KRX, IPAM, KATM (6I4)
3	Elevation of ground zero (m above msl).	ZBRSTZ(E12.5)
4	Soil solidification temperature (°K)	SLDTMP(E12.5)
5	Fission yield (kT)	FW(E12.5)
6	Fraction of energy available in the cloud used to heat air (including ambient water vapor). The remainder is used to heat liquid water.	PHI(E12.5)
7	Atmosphere identification.	ATID(J)(12A6)
8	FORMAT for atmosphere data cards.	FMT(J)(12A6)
9, 10	Atmosphere data scale-transformation parameters.	SCALE(J)(7F10.5/3F10.5)
11	Atmosphere data sequencing indices.	N1, N2, N3, N4, N5, N6, N7, N8 (8I4)
12	Number of altitude levels in the input atmosphere tables.	NPVA(I4)
13	Atmosphere data cards in sequence of increasing altitude (see Table 2.4).	ALT(J), ATP(J), PRS(J), RHZ(J), RLH(J), ETA(J), GRV(J), SLM(J), J=1, NPVA(FMT(I), I=1, 12) (see card 8)

KATM – This controls printout of the atmosphere data table. If the output is requested, the quantities, as labeled and described in Table 2.4, are printed for all 256 altitude intervals.

0 atmosphere data table is not requested
1 atmosphere data table is requested

Atmosphere Data

Subroutine ATMR has been written to provide the utmost in flexibility regarding input of tables of atmospheric properties. The few restrictions on the form and format of presentation of the data to the program are discussed in the description of program ATMR (p. 64). To provide this flexibility it is necessary to require a set of additional inputs that are somewhat complex. The user is cautioned to employ unusual care in the preparation of these inputs and to study carefully the tables of atmospheric properties printed out by subroutine ICRD to ensure that the quantities displayed are precisely as required by the Cloud Rise Module calculations. The additional inputs referred to above are:

1. An object-time FORMAT for use in reading the atmosphere data cards.
2. A list of terms and factors to be used to transform the input data to the proper units.
3. A list of sequencing numbers that tells the program the order in which specific data quantities are punched across the input cards.

Object-time FORMAT specification is a standard FORTRAN function and the user should refer to his FORTRAN coding manual for details.

The lists of adjustment factors and sequencing numbers are closely related. First we discuss the sequencing numbers. As noted in Table 2.3 (card 11), there are eight sequencing numbers punched on a card according to FORMAT (8I4). Each of the I4 fields always is associated with a particular one of the eight atmospheric properties required by the program; this association is given in Table 2.4. The numbers punched in these fields

TABLE 2.4

CORRESPONDENCE OF SEQUENCE CARD FIELDS WITH ATMOSPHERIC DATA

Field Number	Card Column Numbers	Datum Mnemonic	Datum Quantity	Units Required by the Calculations
1	1- 4	ALT	altitude above msl	m
2	5- 8	ATP	temperature	°K
3	9-12	PRS	pressure	mb
4	13-16	RHZ	density	kg/m^3
5	17-20	RLH	relative humidity	%
6	21-24	ETA	viscosity	kg/(m-sec)
7	25-28	GRV	acceleration of gravity	m/sec^2
8	29-32	SLM	mean free path	m

range in value from 1 through 8. For a particular field, for example, the density field, the number punched gives the actual read-in sequence number for density. That is, if a 3 is punched in the density field of the sequence card, this specifies that density will occupy the third field from the left (as defined by the object-time FORMAT card) on the data input card. Suppose our data input card has the following appearance:

Column Number	1–4	4–16	16–28	28–40
Numerical Content	10	225.171	0.414142+3	0.35
Data Specified	Altitude	Temperature	Density	Relative Humidity
Units	km	°K	g/m^3	Fractional

A suitable FORMAT would be

(F4.0, 3E12.6, 4F1.1) .

A suitable sequencing card would be

Column Number	1	4	8	12	16	20	24	28	32
Sequence Number		1	2	5	3	4	6	7	8
Datum Represented	ALT	ATP	PRS	RHZ	RLH	ETA	GRV	SLM	

Note that quantities not specified by input still must be provided for both in the FORMAT and on the sequence cards. Thus, such quantities are read in as zero which indicates that they are to be supplied by the program.*

As with the sequencing numbers, the fields on the scale cards (two scale cards are input) always correspond to specific data quantities. The numbers punched in the scale cards are used to transform the input data to the units specified in Table 2.4. The transformations are performed as follows:

```
ALT(I) = (ALT(I) + SCALE(1)) * SCALE(3)
ATP(I) = (ATP(I) + SCALE(2)) * SCALE(4)
PRS(I) = PRS(I) * SCALE(5)
RHZ(I) = RHZ(I) * SCALE(6)
RLH(I) = RLH(I) * SCALE(7)
```

*The program must have altitude, temperature, relative humidity and either one of density or pressure. Though not required, any or all of the other quantities can be supplied, in which case they are not calculated by the program.

ETA(I) = ETA(I) * SCALE(8)
GRV(I) = GRV(I) * SCALE(9)
SLM(I) = SLM(I) * SCALE(10)

SCALE array entries 3 through 10 are replaced with 1.0 if they are read in as zero. If no transformations are required, blank cards can be used for the scale cards. For the input data example shown on p. 90 the following scale cards would be required:

Card 1

Column Numbers	1	10	20	30	40	50	60	70
Content			1000.			1.0-3	100.	

Card 2

blank

The atmosphere data cards must conform to the object-time FORMAT specified by the user and they must be ordered in sequence of increasing altitude. The altitude increments between cards are arbitrary, however, and there are no restrictions on the specific altitudes supplied by input other than that they should lie in the range -1,000 to 50,000 m relative to mean sea level. The program automatically will build tables of 256 entries each of atmospheric properties in the range of altitude from -1,000 through 50,000 (relative to msl) at intervals of 200 m.

OUTPUT DESCRIPTION

The output is of two kinds: (1) printed, and (2) binary on a peripheral storage unit for use by subsequent modules.

Printed Output

The normal printed output is designed to be self explanatory and thus needs little description here. It is displayed in a later section titled "Sample Problem and Printout." Notice that the atmosphere table headings use the FORTRAN mnemonics as described in Table 2.4. Units for the atmosphere table quantities are as given in Table 2.4.

CRM Debug Printout. The debug outputs are completely labeled with their FORTRAN mnemonics. The quantities printed are as follows:

ST	Time
U	cloud rise velocity
X	Water vapor mixing ratio
T	cloud temperature
R	horizontal cloud radius
Z	cloud center altitude
EK	turbulent kinetic energy density
V	cloud volume
WT	total water mixing ratio
TE	ambient temperature
RM	cloud mass
ES	saturation vapor pressure of water in the cloud
P	ambient pressure
PW	water vapor pressure in the cloud
ED	loss rate of eddy viscous kinetic energy
RLH	ambient relative humidity
S	condensed matter mixing ratio
EPS	kinetic energy density loss rate
RZT	vertical cloud radius
CMLR	total (for all size classes) fallout loss rate

Also printed are statements indicating switch-over from dry-mode to wet-mode and vice versa.

RSXP Debug Printout. This printout gives properties of the cloud wafers (see Figure 2.1) before they are sectioned in the horizontal plane. The printout column headings are defined as follows:

TIM	time (sec)
ALT	altitude of wafer center of mass (m above msl)
RAD	radius (m)
DIAM	particle size class midrange diameter (μm)
MASS	total particulate mass in the wafer (kg)
DZ	wafer thickness (m)
ZLOW	wafer bottom altitude (m above msl)
VOL	wafer volume (m^3)
MBT	(always = 1) signifies that both wafer top and bottom have been processed
IFLAG	a parameter that signifies whether a wafer is part of the cloud cap or stem. If it is totally or partially in the stem, further vertically subdivided wafers are printed out next.

IFLAG = 1 no further subdivision required

IFLAG = 2 further subdivision required.

Binary Output

A binary output onto a peripheral storage unit, logical designation IRISE, is written in subroutine RSXP to communicate data to the Cloud Rise Transport Interface Module. The content of this unit is described in Table 2.5. Units for quantities specified are mks except where noted otherwise. Note that unit IRISE also is used in ATMR for temporary storage in case the input atmospheric property tables must be expanded (see p. 64 ff.).

TABLE 2.5

CONTENT OF CLOUD RISE MODULE
BINARY OUTPUT

Record Number	Content	Variable Names
1	Cloud Rise Module output tape identifier symbol, 'RISE.	DENT
2	Fission yield (kT), cloud soil burden, temperature of soil solidification, time of soil solidification, geometric standard deviation of the (log-normal) particle-diameter volume-frequency distribution. total yield (kT), height of burst above GZ, base edge length of a basic cloud subdivision, fallout particle density, wafer horizontal subdivision factor, maximum cloud radius, elevation of ground zero.	FW, SSAM, SLDTMP, TMSD, SD, W, HEIGHT, BZ, RFD, IRAD, CX(5, MCX), ZBRSTZ
3	Cloud Rise Module run identification.	DNID(J), J=1, 12
4	Initial Conditions Module run identification.	DETID(J), J=1, 12
5	Number of particle size classes.	NDSTR
6	Tables of central particle diameter, volume (mass) fraction, upper boundary diameter (μm), for the particle size classes.	PS(J), FMASS(J), DIAM(J), J=1, NDSTR
7	Number of vertical wafer subdivisions per particle size class.	KDPST
8	Number of altitude levels in the atmosphere tables.	NPVA (=256)
9	Atmosphere altitude, viscosity and density tables.	ALT(J), ETA(J), RHZ(J), J=1, NPVA
10	Number of time entries in the cloud rise history tables, CX.	MCX
11	Tables of cloud bottom height, top height, time, bottom velocity, and top velocity.	CX(3, J), CX(4, J), CX(1, J) CX(6, J), CX(7, J), J=1, MCX
12	Number of entries in wind data table.	NHODO
13	Wind stratum center altitude, x-component of wind velocity, y-component of wind velocity. (This record is omitted if NHODO =0)	ZV(J), VX(J), VY(J), J=1, NHODO

TABLE 2.5 (Cont'd.)

CONTENT OF CLOUD RISE MODULE
BINARY OUTPUT

Record Number	Content	Variable Names
14	Block count of cloud subdivisions.	LODD
15	Block of cloud subdivision properties: x and y coordinates of center of mass relative to ground zero, time relative to detonation, central particle diameter, mass of fallout, altitude of center of mass above msl, cloud subdivision radius at the center of mass, cloud subdivision thickness, altitude of the subdivision bottom above msl, volume of the subdivision.	GDPST(I, J), I = 1, 10, J = 1, LODD
16	Block count.	LODD
17	Block of cloud subdivision properties.	GDPST(I, J), I = 1, 10, J = 1, LODD
N	Zero block count to signal end of tape.	LODD = 0

FORTRAN LISTINGS

The FORTRAN listings are included on pp. 98 through 142. Note that the glossary of mnemonics for all programs is at the beginning of subroutine LINK2 (p. 98 ff.).

LIST OF FORTRAN LISTINGS

```
      SUBROUTINE LINK2
C
C  ALT    - ARRAY(260), ATMOSPHERE ALTITUDE IN METERS(MSL) CORRESPONDING
C           TO ATP, ETA, GRV, PHS, RHZ, RLH, SLM
C  AP     - ARRAY(8), TEMPORARY STORAGE USED IN ATMR
C  AREAMX - MAXIMUM PROJECTED AREA ON THE GROUND BELOW STABILIZED CLOUD
C  ATMR   - SUBROUTINE, READS IN TABLES OF ALT,ATP,ETA,PHS,RHZ,RLH,GRV,
C           SLM
C  ATID   - ARRAY(12), 72 ALPHANUMERIC CHARACTERS FOR
C           ATMOSPHERE IDENTIFICATION
C  ATP    - ARRAY(260), ATMOSPHERE TEMPERATURE (K) MATCHES ALT
C  BARMU  - MEDIAN DIAMETER OF THE LOGNORMAL PARTICLE SIZE VS. MASS
C           DISTRIBUTION
C  BZ     - DEPOSIT INCREMENT LINEAR DIMENSION(CX(5,MCX)/IRAD)
C  BO     - PARAMETER USED TO DETERMINE CLOUD VERTICAL RADIUS
C  CG     - ARRAY(200), FALLING SPEEDS OF PARTICLES IN THE CLOUD
C           (M/SEC)
C  CHANGE - CLOUD TIME AFTER WHICH STEP LENGTH CHANGES TO DST2
C  CL     - LATENT HEAT OF VAPORIZATION OF WATER
C  CMLR   - CLOUD MASS LOSS RATE OF PARTICULATE FALLOUT
C  CP     - SPECIFIC HEAT OF AIR
C  CPAI   - SPECIFIC HEAT OF AIR INTEGRATED FROM TE TO T
C  CPFR   - SUBROUTINE, COMPUTES PARTICLE FALLOUT RATE DURING CLOUD
C           RISE CALCULATIONS
C  CPV    - SUBROUTINE, COMPUTES INITIAL CRM VARIABLES
C  CR     - WEIGHTED AVERAGE SPECIFIC HEAT FOR AIR AND SOIL
C  CRM    - SUBROUTINE, COMPUTES CLOUD RISE AND EXPANSION VARIABLES
C  CRMW   - SUBROUTINE, PRINTS CRM OUTPUT
C  CX     - ARRAY(10,90), CLOUD DIMENSIONS VS. TIME
C           (1,J) - TIME(SEC) AFTER BURST
C           (2,J) - CLOUD TIME INTERVAL(SEC) BEGINNING AT CX(1,J)
C           (3,J) - CLOUD BASE(M) AT CX(1,J)
C           (4,J) - CLOUD TOP(M) AT CX(1,J)
C           (5,J) - CLOUD RADIUS(M) AT CX(1,J)
C           (6,J) - CLOUD BASE RATE (M/SEC) DURING CX(2,J)
C           (7,J) - CLOUD TOP  RATE (M/SEC) DURING CX(2,J)
C           (8,J) - CLOUD RADIAL RATE(M/SEC) DURING CX(2,J)
C           (9,J) - CLOUD TEMPERATURE (K) AT CX(1,J)
C           (10,J) - IN-CLOUD GAS DENSITY (KG/M**3) AT CX(1,J)
C  CXPN   - SUBROUTINE, TABULATES CX ARRAY
C  C2     - CONSTANT USED IN EDDY VISCOSITY MOMENTUM GENERATION
C           (YIELD DEPENDENT)
C  C3     - CONSTANT USED IN COMPUTING TURBULENT ENERGY DISSIPATION RATE
C  C6     - CONSTANT USED IN COMPUTING AIR ENTRAINMENT RATE INTO CLOUD
C           CAUSED BY WIND SHEAR
C  DEK    - DERIVATIVE OF EK
C  DENT   - DATA STATEMENT USED FOR IDENTIFICATION OF IRISE TAPE
C  DERIV  - SUBROUTINE, EVALUATES DERIVATIVES OF CLOUD RISE VARIABLES
C  DETID  - ARRAY(12), 72 ALPHANUMERIC DETONATION IDENTIFICATION CARD
C  DIAM   - ARRAY(201), UPPER BOUNDARY OF I-TH PARTICLE SIZE CLASS.
C           THE LAST ENTRY IN THE ARRAY IS THE LOWER BOUNDARY OF THE
C           LAST(SMALLEST) PARTICLE SIZE CLASS. THE LENGTH OF THE DIAM
C           ARRAY IS ALWAYS ONE GREATER THAN THE NUMBER OF SIZE CLASSES.
C  DNID   - ARRAY(12), 72 ALPHANUMERIC RUN IDENTIFICATION
C  DNS    - FALLOUT PARTICLE DENSITY (GM/CM**3)
C           IF NOT PUNCHED, DNS = 2.6
C  DPST   - ARRAY(8,2),  DEPOSIT INCREMENT VARIABLES COMPILED IN
```

```
C             SUBROUTINE RSXP. THE SECOND INDEX IS NEEDED ONLY IN THE RSXPLINK2058
C             CALCULATIONS TO DISTINGUISH THE INCREMENT TOP FROM THE      LINK2059
C             INCREMENT BOTTOM.                                           LINK2060
C             (1,MBT) - TIME  (SEC) OF ALTITUDE STABILIZATION OR GROUNDINGLINK2061
C             (2,MBT) - ALTITUDE OF INCREMENT CENTER OF MASS (METERS)     LINK2062
C             (3,MBT) - INCREMENT RADIUS AT CENTER OF MASS (METERS)       LINK2063
C             (4,MBT) - MEAN PARTICLE DIAMETER  (MICROMETERS)             LINK2064
C             (5,MBT) - INCREMENT MASS (KGM.)                             LINK2065
C             (6,MBT) - INCREMENT VERTICAL THICKNESS (METERS)             LINK2066
C             (7,MBT) - ALTITUDE OF INCREMENT BOTTOM (METERS)             LINK2067
C             (8,MBT) - INCREMENT VOLUME  (CUBIC METERS)                  LINK2068
C  DPSTK  - NUMBER OF DEPOSIT INCREMENTS PER PARTICLE SIZE CLASS          LINK2069
C  DPX    - ARRAY(2,90), DEPOSIT INCREMENT RISE AND EXPANSION VARIABLE    LINK2070
C             (1,J) - LIFT RATE FACTOR ABOVE CLOUD BASE (1/SEC)           LINK2071
C             (2,J) - LIFT RATE FACTOR BELOW CLOUD BASE (1/SEC)           LINK2072
C  DRM    - DERIVATIVE OF RM                                              LINK2073
C  DS     - DERIVATIVE OF S                                               LINK2074
C  DST    - INTEGRATION TIME STEP                                         LINK2075
C  DSTO   - INITIAL INTEGRATION TIME STEP                                 LINK2076
C  DST1   - INTERMEDIATE INTEGRATION TIME STEP                            LINK2077
C  DST2   - FINAL VALUE OF INTEGRATION TIME STEP                          LINK2078
C  DT     - DERIVATIVE OF T                                               LINK2079
C  DU     - DERIVATIVE OF U                                               LINK2080
C  DVBL   - ARRAY(8), USED TO TRANSMIT VARIABLE DERIVATIVES               LINK2081
C  DWT    - DERIVATIVE OF WT                                              LINK2082
C  DX     - DERIVATIVE OF X                                               LINK2083
C  DZ     - DERIVATIVE OF Z                                               LINK2084
C  ED     - EDDY VISCOSITY LOSS RATE OF KINETIC ENERGY OF RISE            LINK2085
C  EK     - TURBULENT KINETIC ENERGY DENSITY                              LINK2086
C  EPS    - KINETIC ENERGY LOSS RATE                                      LINK2087
C  ERROR  - SUBROUTINE, FOR GENERAL UTILITY INDICATION                    LINK2088
C  ES     - SATURATION PRESSURE OF WATER VAPOR (INVALID FOR TEMPERATURE LINK2089
C             ABOVE BOILING POINT OF WATER)                               LINK2090
C  ETA    - ARRAY(260), ATMOSPHERIC DYNAMIC VISCOSITY (=COEFF. OF VISC.)LINK2091
C             (KGM/(M-SEC)) MATCHES ALT ARRAY                             LINK2092
C  EXTM   - IN SUBROUTINE RSXP, TIME INCREMENT BETWEEN WAFER HISTORY      LINK2093
C             DESCRIPTION POINTS                                          LINK2094
C  F      - FRACTION OF W IN FIREBALL AT START OF RISE                    LINK2095
C  FMASS  - ARRAY(200),PARTICLE SIZE CLASS FRACTION OF TOTAL MASS LIFTEDLINK2096
C  FMT    - OBJECT TIME FORMAT USED TO READ ATMOSPHERE TABLES             LINK2097
C  FROG   - CONSTANT USED IN COMPUTING PARTICLE FALL RATES                LINK2098
C  FW     - FISSION YIELD IN KILOTONS                                     LINK2099
C  GDPST  - ARRAY(10,100), DEPOSIT INCREMENT VARIABLES (OUTPUT OF RSXP) LINK2100
C             (1,J) - DEPOSIT INCREMENT X COORDINATE (METERS)             LINK2101
C             (2,J) - DEPOSIT INCREMENT Y COORDINATE (METERS)             LINK2102
C             (3,J) - TIME COORDINATE (SEC)                               LINK2103
C             (4,J) - PARTICLE DIAMETER (METERS)                          LINK2104
C             (5,J) - DEPOSIT INCREMENT MASS (KGM)                        LINK2105
C             (6,J) - Z COORDINATE OF INCREMENT CENTER OF MASS (METERS)   LINK2106
C             (7,J) - INCREMENT RADIUS AT CENTER OF MASS (METERS)         LINK2107
C             (8,J) - INCREMENT VERTICAL THICKNESS (METERS)               LINK2108
C             (9,J) - ALTITUDE OF INCREMENT BOTTOM (METERS)               LINK2109
C             (10,J) - INCREMENT VOLUME (CUBIC METERS)                    LINK2110
C  GRV    - ARRAY(260), ACCELERATION DUE TO GRAVITY(CM/SEC**2)            LINK2111
C  HEIGHT - HEIGHT OF BURST (METERS) ABOVE GROUND ZERO                    LINK2112
C  HLR    - RELATIVE HUMIDITY AT ALTITUDE OF CLOUD CENTER                 LINK2113
C  HOB    - HEIGHT(FT) OF BURST ABOVE GROUND ZERO (ZBRSTZ)                LINK2114
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C  ICRD   - SUBROUTINE, READS LINK2 INPUT CARDS                          LINK2115
C  IDISTR - PARTICLE DISTRIBUTION CONTROL PARAMETER (SET IN LINK1)       LINK2116
C           1 - LOGNORMAL DISTRIBUTION                                  LINK2117
C           2 - POWER LAW DISTRIBUTION                                  LINK2118
C           3 - TABULAR INPUT DISTRIBUTION                              LINK2119
C  IEXEC  - CONTROL INTEGER FOR CALLING PROGRAM LINKS                   LINK2120
C  IPAM   - CONTROL INTEGER FOR PAM OPTION                              LINK2121
C           0 - NO PAM CALL                                             LINK2122
C           1 - CALL PAM                                                LINK2123
C  IRAD   - NUMBER OF CLOUD WAFER RADIUS SUBDIVISIONS (SEE BZ)          LINK2124
C  IRISE  - LOGICAL DESIGNATION FOR TAPE USED FOR TEMPORY STORAGE IN    LINK2125
C           ATMR AND FOR RSXP OUTPUT                                    LINK2126
C  JBASE  - COMPUTED GO TO INDEX USED IN SUBROUTINE RSXP                LINK2127
C           1 - CONTINUE DPST TRAJECTORY COMPUTATION                    LINK2128
C           2 - DPST TRAJECTORY COMPUTATION COMPLETE                    LINK2129
C  KATM   - ATMOSPHERE PRINTOUT SWITCH                                  LINK2130
C           0 - NO ATMOSPHERE PRINTOUT                                  LINK2131
C           1 - ATMOSPHERE PRINTOUT                                     LINK2132
C  KBASE  - COMPUTED GO TO INDEX USED IN SUBROUTINE RSXP                LINK2133
C           1 - ADJUST DPST RADIUS AND ACTIVITY FOR LEAVING CLOUD       LINK2134
C           2 - ADJUSTMENT OF 1 HAS BEEN MADE                           LINK2135
C  KCLD   - CONTROL INDEX FOR CRM DEBUG PRINTOUT,                       LINK2136
C           0 - NO DEBUG PRINT OUT                                      LINK2137
C           1 - DEBUG PRINT OUT                                         LINK2138
C  KCX    - NUMBER OF DPST RISE AND EXPANSION INTERVALS                 LINK2139
C  KDI    - NUMBER OF DEPOSIT INCREMENT PER PSC                         LINK2140
C           IF NOT PUNCHED, IT IS COMPUTED BY PROGRAM                   LINK2141
C           (SEE RSXP)                                                  LINK2142
C  KDIP   - IN SUBROUTINE RSXP, NUMBER OF SUBDIVISIONS OF A WAFER WHOSE LINK2143
C           TOP AND BOTTOM RADII ARE NOT EQUAL                          LINK2144
C  KDPST  - SEE DPSTK                                                   LINK2145
C  KRX    - CONTROL INDEX FOR RSXP DEBUG PRINTOUT                       LINK2146
C           0 - NO DEBUG PRINTOUT                                       LINK2147
C           1 - DEBUG PRINTOUT                                          LINK2148
C  KSV    - INDEX WHICH DETERMINES FUNCTION OF SUBROUTINE RSTR          LINK2149
C           1 - PRESERVE VARIABLES AT START OF TIME STEP                LINK2150
C           2 - RESTORE VARIABLES TO THOSE AT START OF TIME STEP        LINK2151
C  LODD   - LENGTH OF PARTICLE DESCRIPTION DATA BLOCK (GDPST ARRAY IN   LINK2152
C           RSXP)                                                       LINK2153
C  MBT    - IN SUBROUTINE RSXP, DISTINGUISHES A WAFER TOP FROM A WAFER  LINK2154
C           BOTTOM                                                      LINK2155
C           MBT=1 SPECIFIES A WAFER TOP                                 LINK2156
C           MBT=2 SPECIFIES A WAFER BOTTOM                              LINK2157
C  MCX    - NUMBER OF TIME POINTS (ROWS) OF CX ARRAY                    LINK2158
C  MWYA   - 1, INITIAL ENTRY INTO CXPN                                  LINK2159
C           2, REGULAR ENTRY                                            LINK2160
C           3, FINAL ENTRY                                              LINK2161
C  N      - CLOUD MODE SWITCH                                           LINK2162
C  NDSTR  - NUMBER OF ENTRIES IN PARTICLE SIZE CLASS TABLE              LINK2163
C  NHODO  - NUMBER OF ENTRIES IN THE WIND HODOGRAPH TABLE               LINK2164
C  NNN    SPARE                                                         LINK2165
C  NPVA   - NUMBER OF ELEMENTS IN ALT AND CORRESPONDING ARRAYS          LINK2166
C           LIMITS OF NPVA = 1,260                                      LINK2167
C           THE MNEMONIC NPVA IS CHANGED TO NAT IN LINK 4               LINK2168
C  P      - ATMOSPHERIC PRESSURE AT CLOUD CENTER ALTITUDE               LINK2169
C  PHI    - FRACTION OF F*W USED TO HEAT AIR                            LINK2170
C  PPST   - ARRAY(8,10), TEMPORARY STORAGE OF DEPOSIT INCREMENT         LINK2171
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C               VARIABLES IN RSXP FOR WAFER SUBDIVISIONS                   LINK2172
C   PRS      - ARRAY(260) ATMOSPHERIC PRESSURE (MB)  MATCHES ALT           LINK2173
C   PS       - ARRAY(200), PARTICLE SIZE CLASS MIDPOINT DIAMETER (METERS)  LINK2174
C   PSIZE    - PARTICLE SIZE CLASS MIDPOINT(MICROMETERS)USED IN SUBR. CPFR LINK2175
C   PW       - PARTIAL PRESSURE OF WATER VAPOR IN THE CLOUD                LINK2176
C   Q        - CONVERSION FACTOR FOR FRACTION MASS TO NUMBER OF PARTICLES  LINK2177
C                       PER M**3                                           LINK2178
C   QI       - VIRTUAL MASS FACTOR TERM IN CLOUD EQUATION OF MOTION        LINK2179
C   QX       - FACTOR CONVERTS CLOUD TEMPERATURE TO VIRTUAL CLOUD          LINK2180
C              TEMPERATURE                                                 LINK2181
C   QXE      - INVERSE OF FACTOR TO CONVERT AMBIENT TEMPERATURE TO         LINK2182
C              VIRTUAL AMBIENT TEMPERATURE                                 LINK2183
C   R        - CLOUD HORIZONTAL RADIUS                                     LINK2184
C   RA       - GAS DENSITY OF CLOUD                                        LINK2185
C   RADIUS   - DEPOSIT INCREMENT RADIUS USED IN SUBROUTINE RSXP            LINK2186
C   RFD      - DENSITY OF EXTRA MATERIAL IN CLOUD(MKS)(EQUALS DNS*1000.)   LINK2187
C   RHZ      - ARRAY(260)  ATMOSPHERE AIR DENSITY (KGM/M**3), MATCHES ALT. LINK2188
C              THE MNEMONIC RHZ IS CHANGED TO RHO IN LINK 4.               LINK2189
C   RKGILL   - SUBROUTINE, USES RUNGE-KUTTA METHOD TO INTEGRATE            LINK2190
C              DIFFERENTIAL EQUATIONS OF CLOUD                             LINK2191
C              (SEE CRM)                                                   LINK2192
C   RL       - EMPIRICAL CONSTANT USED TO CALCULATE ENTRAINMENT RATE AND   LINK2193
C              CLOUD VERTICAL RADIUS                                       LINK2194
C   RLH      - ARRAY(260)  ATMOSPHERE RELATIVE HUMIDITY MATCHES ALT        LINK2195
C   RM       - CLOUD MASS                                                  LINK2196
C   RMAO     - INITIAL AIR MASS OF CLOUD                                   LINK2197
C   RMIN     - MINIMUM PARTICLE RADIUS (MICROMETERS IN LINK1 CONVERTED TO  LINK2198
C              METERS IN SUBR. CPV FOR USE THROUGHOUT LINK2)               LINK2199
C   RMWO     - INITIAL WATER MASS OF CLOUD                                 LINK2200
C   RSTR     - SUBROUTINE WHICH PRESERVES AND/OR RESTORES CRM VARIABLES    LINK2201
C   RSXP     - SUBROUTINE, RISE AND EXPANSION MODEL  WHICH COMPUTES        LINK2202
C              DEPOSIT INCREMENT POSITIONS THROUGHOUT CLOUD RISE HISTORY   LINK2203
C   RZT      - VERTICAL CLOUD RADIUS                                       LINK2204
C   S        - CONDENSED SOIL MIXING RATIO                                 LINK2205
C   SCALE    - ARRAY(10) , ATMOSPHERE TABLE ADJUSTMENT FACTORS             LINK2206
C   SD       - PARTICLE SIZE GEOMETRIC STANDARD DEVIATION SUPPLIED BY LINK1LINK2207
C              (DIMENSIONLESS).  IF NOT PUNCHED, SD = 4.0                  LINK2208
C              APPLICABLE ONLY FOR THE LOGNORMAL DISTRIBUTION              LINK2209
C   SLDTMP   - PARTICLE SOLIDIFICATION TEMPERATURE (K)                     LINK2210
C   SLM      - ARRAY(260)  ATMOSPHERE MEAN FREE PATH OF AIR MOLECULES(M)   LINK2211
C              MATCHES ALT                                                 LINK2212
C   SMALLT   - TIME AFTER START OF COMPUTATION                             LINK2213
C   SOILHT   - LATENT HEAT OF VAPORIZATION OF CLOUD SOIL CONSTITUENT       LINK2214
C   SSAM     - TOTAL SOIL MASS (KG)                                        LINK2215
C   SZRO     - S AT INITIAL TIME                                           LINK2216
C   T        - CLOUD TEMPERATURE (K)                                       LINK2217
C   TE       - ATMOSPHERIC TEMPERATURE AT CLOUD CENTER ALTITUDE            LINK2218
C   TME      - INITIAL TIME (SEC) SUPPLIED BY LINK1                        LINK2219
C   TMP1     - INITIAL VAPOR TEMPERATURE (K) SUPPLIED BY LINK1             LINK2220
C   TMP2     - INITIAL TEMPERATURE OF CONDENSED PHASE MATERIAL IN CLOUD    LINK2221
C              SUPPLIED BY LINK1(NOT USED)                                 LINK2222
C   TMSD     - TIME OF PARTICLE SOLIDIFICATION (SEC) WITHIN CLOUD          LINK2223
C   TRPL     - SUBROUTINE, USES LINEAR INTERPOLATION TO COMPUTE VARIABLE   LINK2224
C              CORRESPONDING TO ARGUMENT                                   LINK2225
C   TSRD     - R-RATE CLOUD RISE TERMINATION SWITCH PARAMETER              LINK2226
C   TSTM     - TIME AT WHICH NEXT CX ARRAY ENTRIES ARE TO BE MADE          LINK2227
C   U        - CLOUD VERTICAL VELOCITY                                     LINK2228
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C  USOIL   - SOIL TYPE, 1.0 = SILICEOUS
C                       2.0 = CALCAREOUS
C            IF NOT PUNCHED, USOIL = 1.0
C  V       - CLOUD VOLUME
C  VBL     - ARRAY(8), DUMMY VARIABLES OF INTEGRATION(SUBS. DERIV,RKGILL)
C  VIS     - DYNAMIC VISCOSITY OF IN-CLOUD GAS(KGM./M./SEC.) (SUBR. CPFR)
C  VPR     - MASS OF VAPOR (KG) SUPPLIED BY LINK1
C  VX(I)   - ARRAY(200), X-COMPONENT OF WIND VELOCITY AT WIND HODOGRAPH
C            STRATUM I, (METERS/SEC)
C  VY(I)   - ARRAY(200), Y-COMPONENT OF WIND VELOCITY AT WIND HODOGRAPH
C            STRATUM I, (METERS/SEC)
C  W       - TOTAL YIELD (KT)
C  WT      - SOLID AND LIQUID WATER MIXING RATIO
C  X       - IN-CLOUD WATER VAPOR MIXING RATIO
C  XE      - AMBIENT AIR WATER VAPOR MIXING RATIO
C  Y       - ARRAY(200),NUMBER OF IN-CLOUD PARTICLES/UNIT VOLUME OF CLOUD
C  Z       - CLOUD CENTER ALTITUDE (METERS)
C  ZBFR    - MAXIMUM Z OF CURRENT OR PREVIOUS ENTRIES TABULATED BY CXPR-
C  ZBRSTZ  - Z-COORDINATE OF BURST GROUND ZERO (METERS ABOVE MSL)
C  ZLMT    - UPPER LIMIT FOR CLOUD CENTER ALTITUDE TO PREVENT POSSIBLE
C            COMPUTATIONAL RUNAWAY
C  ZV(I)   - ALTITUDE OF CENTER PLANE OF WIND HODOGRAPH STRATUM I
C            (METERS ABOVE MSL)
C  ZVSB    - IN SUBROUTINE RSXP, DISTANCE OF A WAFER ABOVE CLOUD BASE
C
C ************************************************************************
C
C
C***************LINK2*****************
C
C
      COMMON /SET1/
     1CAY         ,DETID(12)  ,DIAM(201)  ,DMEAN      ,DNS        ,EXPO       ,
     2FMASS(200)  ,IDISTR     ,IEXEC      ,IRISE      ,ISIN       ,ISCOUT     ,
     3NDSTR       ,PS(200)    ,SD         ,SSAM       ,TME        ,TMP1       ,
     4TMP2        ,T2M        ,USOIL      ,VPR        ,W          ,HEIGHT     ,
     5ZSCL        ,NHODO      ,ZV(200)    ,VX(200)    ,VY(200)
      COMMON /CLOUD/
     1ALT(260)    ,ATP(260)   ,B0         ,CG(200)    ,CHANGE     ,CMLR       ,
     2CX(10,90)   ,C2         ,C3         ,C6         ,DEK        ,DNID(12)   ,
     3DRM         ,DS         ,DST        ,DSTO       ,DST1       ,DST2       ,
     4DT          ,DU         ,DWT        ,DX         ,DZ         ,ED         ,
     5EK          ,EPS        ,ES         ,ETA(260)   ,F          ,FW         ,
     6GRV(260)    ,HLR        ,HOB        ,IPAM       ,IRAD       ,KCLD       ,
     7KDI         ,KRX        ,KS         ,KSV        ,MCX        ,MWYA       ,
     8N           ,NNN        ,NPVA       ,P          ,PRS(260)   ,PW         ,
     9QI          ,R          ,RA         ,RFD        ,RHZ(260)   ,RL         ,
     1RLH(260)    ,RM         ,RZT        ,S          ,SAVE       ,SLDTMP     ,
     2SLM(260)    ,SMALLT     ,SZRO       ,T          ,TE         ,TMSD       ,
     3U           ,V          ,VZRO       ,WT         ,X          ,XE         ,
     4Y(200)      ,Z          ,ZBFR       ,ZBRSTZ     ,ZLMT
C
C
      DIMENSION CXTIM(90),CXTMP(90)
C
C
      HOB=HEIGHT*3.2808333
```

```
      SSAM=SSAM+VPR
      CALL ICRD
      RFD=1000.*DNS
      CALL CRM
C
C     COMPUTE TIME OF PARTICLE SOLIDIFICATION
C
      DO 122 MA=1,MCX
      MB=MCX-MA+1
      CXTIM(MA)=CX(1,MB)
  122 CXTMP(MA)=CX(9,MB)
      CALL TRPL(SLDTMP,MCX,CXTMP,CXTIM,TMSD)
      WRITE(ISOUT,513)TMSD
  513 FORMAT(/9X,'TIME OF SOIL SOLIDIFICATION = ',F9.4,' SEC')
      IF(IPAM)50,50,60
   60 CALL PAM
   50 CALL RSXP
      RETURN
      END
```

```
      SUBROUTINE ATMR
C
C     REVISED   MAY 1970
C
C
C *****************************************************************
C
C     ATMR READS IN ATMOSPHERE TABLES
C
C     ATMOSPHERE TABLE GLOSSARY- UNITS ARE FOR THE SCALED ENTRIES
C
C   1   ALT - ALTITUDE ABOVE MSL (METERS)
C   2   ATP - TEMPERATURE (DEGREES KELVIN)
C   3   PRS - PRESSURE (MB)
C   4   RHZ - DENSITY (KGM/M**3)
C   5   RLH - RELATIVE HUMIDITY (PERCENT)
C   6   ETA - VISCOSITY (KGM/(M-SEC))
C   7   GRV - ACCELERATION OF GRAVITY  (M/SEC**2)
C   8   SLM - MOLECULAR MEAN FREE PATH (M)
C
C *****************************************************************
C
      COMMON /SET1/
     1CAY       ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,
     2FMASS(200),IDISTR    ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,
     3NDSTR     ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,
     4TMP2      ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,
     5ZSCL      ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)
      COMMON /CLOUD/
     1ALT(260)  ,ATP(260)  ,B0        ,CG(200)   ,CHANGE    ,CMLR      ,
     2CX(10,90) ,C2        ,C3        ,C6        ,DEK       ,DNID(12)  ,
     3DRM       ,DS        ,DST       ,DSTO      ,DST1      ,DST2      ,
     4DT        ,DU        ,DWT       ,DX        ,DZ        ,ED        ,
     5EK        ,EPS       ,ES        ,ETA(260)  ,F         ,FW        ,
     6GRV(260)  ,HLR       ,HOB       ,IPAM      ,IRAD      ,KCLD      ,
     7KDI       ,KRX       ,KS        ,KSV       ,MCX       ,MWYA      ,
     8N         ,NNN       ,NPVA      ,P         ,PRS(260)  ,PW        ,
     9QI        ,R         ,RA        ,RFD       ,RHZ(260)  ,RL        ,
     1RLH(260)  ,RM        ,RZT       ,S         ,SAVE      ,SLDTMP    ,
     2SLM(260)  ,SMALLT    ,SZRO      ,T         ,TE        ,TMSD      ,
     3U         ,V         ,VZRO      ,WT        ,X         ,XE        ,
     4Y(200)    ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
      DIMENSION FMT(18),SCALE(10),ATMSUB(8),ATMZRO(8),ATMMAX(8),AP(8)
C
C *****************************************************************
C
 010  FORMAT(I4)
   20 FORMAT(8I4)
   30 FORMAT(12A6)
   40 FORMAT(7F10.5/3F10.5)
C
C *****************************************************************
C *****************************************************************
C
      DATA PROGRM/6H ATMR
      DATA ATMSUB
     1             /-1000.,294.66,.1347E+1,.18206E-4,.1139E4, 9.8,
```

```
      2 .60323E-7,77./
        DATA ATMZRO
      1               / 0.0,288.18,.12250E+1,.17894E-4,.10133E4, 9.8,
      2 .66317E-7, 77./
        DATA ATMMAX
      1               /50000.,282.66,.10829E+1,.17628E-4,.87858,9.6542,
      2 .75023E-4, 0.0/
C
        IGO=0
        NBRNCH=1
        WATCOR=(1.-18./29.)/100.
C
C       READ OBJECT-TIME FORMAT
C
        READ(ISIN,30)FMT
C
C       READ SCALE AND ADJUSTMENT FACTORS
C
        READ(ISIN,40)SCALE
        DO 90 I=3,10
        IF(SCALE(I))90,91,90
     91 SCALE(I)=1.
     90 CONTINUE
C
C       READ ATMOSPHERE DATA SEQUENCE INDICIES
        READ(ISIN,20)N1,N2,N3,N4,N5,N6,N7,N8
C
C       READ NUMBER OF ATMOSPHERE TABLE ENTRIES
C
        READ(ISIN,10)NPVA
C
C       READ ATMOSPHERE TABLE ENTRIES, SEQUENCE AND ADJUST THEM TO THE
C       PROPER UNITS, AND WHERE APPROPRIATE COMPUTE THOSE ENTRIES NOT
C       PROVIDED IN THE INPUT.  ETA, GRV, AND SLM NEED NOT BE INPUT.
C       EITHER PRS OR RHZ (BUT NOT BOTH) NEED NOT BE INPUT
C
        DO 100 I=1,NPVA
        READ(ISIN,FMT)AP
        ALT(I)=(AP(N1)+SCALE(1))*SCALE(3)
        ATP(I)=(AP(N2)+SCALE(2))*SCALE(4)
        PRS(I)=AP(N3)*SCALE(5)
        RHZ(I)=AP(N4)*SCALE(6)
        RLH(I)=AP(N5)*SCALE(7)
        ETA(I)=AP(N6)*SCALE(8)
        GRV(I)=AP(N7)*SCALE(9)
        SLM(I)=AP(N8)*SCALE(10)
C
C       ARE SUCCESSIVE TABLE ENTRIES IN ORDER OF INCREASING ALTITUDE-
C
        IF(I.EQ.1) GO TO 50
        IF (ALT(I)-ALT(I-1)) 45,45,50
     45 IRROR=-45
        PRINT 40, ALT(I),ALT(I-1)
        GO TO 130
     50 IF(GRV(I).GT.0.0) GO TO 70
        GRV(I)=9.8
     70 IF(ETA(I) .GT.0.0) GO TO 1070
```

```
      ETA(I)=1.458E-6*ATP(I)**1.5/(110.4+ATP(I))
 1070 IF(PRS(I).GT.0.0) GO TO 73
      IF(RHZ(I).GT.0.0) GO TO 72
   71 IRROR=-71
      GO TO 130
   72 ES= 6.11*(273./ATP(I))**5.13* EXP(25.*(ATP(I)-273. )/ATP(I))
      PRS(I)= 2.8679* RHZ(I)*ATP(I) +ES*RLH(I)*WATCOR
      GO TO 60
   73 IF(RHZ(I).GT.0.0) GO TO 60
      ES= 6.11*(273./ATP(I))**5.13* EXP(25.*(ATP(I)-273. )/ATP(I))
      RHZ(I)= (PRS(I)-ES*RLH(I)*WATCOR)/(2.8679*ATP(I))
   60 IF(SLM(I) .GT.0.0) GO TO 100
      SLM(I)=2.33239E-7*ATP(I)/PRS(I)
  100 CONTINUE
C
C     DETERMINE IF THE TABLE MUST BE EXPANDED TO 256 ENTRIES
C
  110 IF(NPVA-256)140,111,120
C
C 111 THE TABLES DO NOT NEED EXPANSION.  CHECK TO DETERMINE IF THE
C     TABLES HAVE THE PROPER BOUNDRIES.
C
  111 IF(ABS(ALT(1)+ 1000.).LE.1.) GO TO 113
  112 IRROR=-112
      GO TO 130
  113 IF(ABS(ALT(256)-5.E4).LE.50.) GO TO 115
  114 IRROR=-114
      GO TO 130
C
C 115 THE TABLES HAVE THE PROPER BOUNDRIES.  CHECK TO DETERMINE IF THE
C     ALTITUDE INTERVALS ARE ALL 200 METERS.
C
  115 DO 116 I=2,256
      IF(ABS(ALT(I)-ALT(I-1)-200.).GT.2.) GO TO 135
  116 CONTINUE
      GO TO 270
  120 IRROR=-120
  130 CALL ERROR(PROGRM,IRROR,ISOUT)
  135 CONTINUE
      GO TO (140,137),NBRNCH
  137 IRROR=-137
      GO TO 130
C
C 140 THE TABLES NEED EXPANSION OR INTERVAL ADJUSTMENT
C
  140 REWIND IRISE
C
C     DO THE TABLES BEGIN AT -1000 METERS-
C     IF NOT MAKE AN ENTRY AT -1000 METERS FROM THE ARDC STANDARD ATMOS.
C
      IF(ABS(ALT(1)+1000.) .GT. 1.) GO TO 150
      ALT(1)=-1000.
      GO TO 200
  150 WRITE(IRISE)ATMSUB
  160 IGO=IGO+1
C
C     DO THE TABLES HAVE AN ENTRY AT      0 METERS-
```

```
C     IF NOT MAKE AN ENTRY AT      0 METERS FROM THE ARDC STANDARD ATMOS.
C
      IF(ALT(1)    .LE. 0.001)GO TO 200
      WRITE(IRISE)ATMZRO
      IGO=IGO+1
C
C     STORE THE INPUT TABLES ON TAPE
C
  200 DO 210 I=1,NPVA
  210 WRITE(IRISE)ALT(I),ATP(I),RHZ(I),ETA(I),PRS(I),GRV(I),SLM(I),
     1 RLH(I)
C
C     DO THE TABLES HAVE AN ENTRY AT 50000 METERS-
C     IF NOT MAKE AN ENTRY AT 50000 METERS FROM THE ARDC STANDARD ATMOS.
C
      IF(ALT(NPVA) .GE. 5.E4) GO TO 220
      IF(ABS(ALT(NPVA)-5.E4).LE.50.)GO TO 220
      WRITE(IRISE)ATMMAX
      NPVA=NPVA+1
C
C     INITIALIZE FOR THE TABLES EXPANSION
C
  220 REWIND IRISE
      NPVA=NPVA+IGO
      IF(NPVA-256)222,222,221
  221 IRROR=-221
      GO TO 130
  222 DALT=200.
      NPV=1
      READ(IRISE)ALT(1),ATP(1),RHZ(1),ETA(1),PRS(1),GRV(1),SLM(1),
     1 RLH(1)
      A1=ALT(1)
      A2=ATP(1)
      A3=RHZ(1)
      A4=ETA(1)
      A5=PRS(1)
      A6=GRV(1)
      A7=SLM(1)
      A8=RLH(1)
C
C     EXPAND THE TABLES TO 256 ENTRIES IN 200 METERS INTERVALS IN
C     ALTITUDE FROM -1000 TO 50000 METERS BY LINEAR INTERPOLATION
C     FROM THE  INPUT TABLES
C
      DO 260 I=2,256
      ALT(I)=ALT(I-1)+DALT
  225 IF(A1.GE.ALT(I))GO TO 250
      IF(ALT(I)-A1 .LT. 2.) GO TO 250
      NPV=NPV+1
      IF(NPVA-NPV .GE.0)GO TO 240
  230 IRROR=-230
      GO TO 130
  240 READ(IRISE)A1,A2,A3,A4,A5,A6,A7,A8
      GO TO 225
  250 TERP=  DALT       /(A1-ALT(I-1))
      ATP(I)=ATP(I-1)+TERP*(A2-ATP(I-1))
      RHZ(I)=RHZ(I-1)+TERP*(A3-RHZ(I-1))
```

```
      ETA(I)=ETA(I-1)+TERP*(A4-ETA(I-1))                                ATMR 229
      PRS(I)=PRS(I-1)+TERP*(A5-PRS(I-1))                                ATMR 230
      GRV(I)=GRV(I-1)+TERP*(A6-GRV(I-1))                                ATMR 231
      SLM(I)=SLM(I-1)+TERP*(A7-SLM(I-1))                                ATMR 232
      RLH(I)=RLH(I-1)+TERP*(A8-RLH(I-1))                                ATMR 233
  250 CONTINUE                                                          ATMR 234
      NPVA=256                                                          ATMR 235
      NBRNCH=2                                                          ATMR 236
      GO TO 111                                                         ATMR 237
  270 RETURN                                                            ATMR 238
      END                                                               ATMR 239
```

```
      SUBROUTINE CPFR                                                   CPFR 001
C                                                                       CPFR 002
C ***********************************************************************CPFR 003
C                                                                       CPFR 004
C     CPFR COMPUTES PARTICLE FALLOUT RATE                               CPFR 005
C                                                                       CPFR 006
C ***********************************************************************CPFR 007
C                                                                       CPFR 008
      COMMON /SET1/                                                     CPFR 009
     1CAY        ,DETID(12) ,DIAM(201) ,DMEAN      ,DNS       ,EXPO      ,CPFR 010
     2FMASS(200) ,IDISTR    ,IEXEC     ,IRISE      ,ISIN      ,ISOUT     ,CPFR 011
     3NDSTR      ,PS(200)   ,SD        ,SSAM       ,TME       ,TMP1      ,CPFR 012
     4TMP2       ,T2M       ,USOIL     ,VPR        ,W         ,HEIGHT    ,CPFR 013
     5ZSCL       ,NHODO     ,ZV(200)   ,VX(200)    ,VY(200)              CPFR 014
      COMMON /CLOUD/                                                    CPFR 015
     1ALT(260)   ,ATP(260)  ,B0        ,CG(200)    ,CHANGE    ,CMLR      ,CPFR 016
     2CX(10,90)  ,C2        ,C3        ,C6         ,DEK       ,DNID(12)  ,CPFR 017
     3DRM        ,DS        ,DST       ,DSTO       ,DST1      ,DST2      ,CPFR 018
     4DT         ,DU        ,DWT       ,DX         ,DZ        ,ED        ,CPFR 019
     5EK         ,EPS       ,ES        ,ETA(260)   ,F         ,FW        ,CPFR 020
     6GRV(260)   ,HLR       ,HOB       ,IPAM       ,IRAD      ,KCLD      ,CPFR 021
     7KDI        ,KRX       ,KS        ,KSV        ,MCX       ,MWYA      ,CPFR 022
     8N          ,NNN       ,NPVA      ,P          ,PRS(260)  ,PW        ,CPFR 023
     9QI         ,R         ,RA        ,RFD        ,RHZ(260)  ,RL        ,CPFR 024
     1RLH(260)   ,RM        ,RZT       ,S          ,SAVE      ,SLDTMP    ,CPFR 025
     2SLM(260)   ,SMALLT    ,SZRO      ,T          ,TL        ,TMSD      ,CPFR 026
     3U          ,V         ,VZRO      ,WT         ,X         ,XE        ,CPFR 027
     4Y(200)     ,Z         ,ZBFR      ,ZBRSTZ     ,ZLMT                 CPFR 028
C                                                                       CPFR 029
C ***********************************************************************CPFR 030
C                                                                       CPFR 031
C ***********************************************************************CPFR 032
C                                                                       CPFR 033
C ***********************************************************************CPFR 034
  903 FORMAT (1H1//////////                                             CPFR 035
     1  20X30HNEGATIVE PARTICLE DENSITY                           //////) CPFR 036
C                                        TEST FOR IMPOSSIBLE PARTICLE   CPFR 037
      DO 901 J=1,NDSTR                                                  CPFR 038
          IF(Y(J)) 902, 901, 901                                        CPFR 039
901       CONTINUE                                                      CPFR 040
          GO TO 900                                                     CPFR 041
  902 WRITE(ISOUT,903)                                                  CPFR 042
      MWYA = 3                                                          CPFR 043
      GO TO 008                                                         CPFR 044
900       CONTINUE                                                      CPFR 045
C                                                                       CPFR 046
C     COMPUTE PARTICLE FALLOUT RATES                                    CPFR 047
C                                                                       CPFR 048
      VIS=1.458E-6*T**1.5/(110.4+T)                                     CPFR 049
      FROG=1.306666E-17*RFD                                             CPFR 050
      DO 3 J=1,NDSTR                                                    CPFR 051
      PSIZE=PS(J)*1.0E+6                                                CPFR 052
      VO=PSIZE/VIS                                                      CPFR 053
      V1=PSIZE*VO*FROG                                                  CPFR 054
      CDRR=V1*VO*RA                                                     CPFR 055
      IF(CDRR-140.0)701,701,749                                         CPFR 056
  749 IF(CDRR-4.5E+7)760,751,751                                        CPFR 057
```

```
751 WRITE(ISOUT,758)PSIZE,Z                                             CPFR 058
758 FORMAT(//'DAVIES EQUATIONS ARE INACCURATE FOR ',F12.3,'MICROMETERSCPFR 059
   1AT',F12.3,'METERS')                                                  CPFR 060
    GO TO 760                                                            CPFR 061
701 CG(J)=V1*(41466.7+CDRR*(-2.3363E+2+CDRR*(2.0154-6.9105E-3*CDRR)))   CPFR 062
    GO TO 3                                                              CPFR 063
760 QLOGA=ALOG10(CDRR)-20.773                                            CPFR 064
    CG(J)=50657.0*V1*CDRR**((QLOGA*QLOGA-443.98)*0.0011235)              CPFR 065
  3 CG(J)=CG(J)*(1.0+0.233/(PSIZE*RA))                                   CPFR 066
C                                                                        CPFR 067
C     COMPUTE OVERALL LOSS RATE OF FALLOUT FROM THE CLOUD AND ADJUST     CPFR 068
C     IN-CLOUD PARTICLE CONCENTRATIONS                                   CPFR 069
C                                                                        CPFR 070
    CMLR=0.                                                              CPFR 071
    A=3.1415927*R**2*DST                                                 CPFR 072
    DO 1 J=1,NDSTR                                                       CPFR 073
    C=0.5235988*PS(J)**3                                                 CPFR 074
    D=A*CG(J)                                                            CPFR 075
    CMLR=CMLR+C*D*Y(J)                                                   CPFR 076
  1 Y(J)=Y(J)*(1.-D/V)                                                   CPFR 077
    CMLR=CMLR*RFD/DST                                                    CPFR 078
008 RETURN                                                               CPFR 079
    END                                                                  CPFR 080
```

```
      SUBROUTINE CPV
C
C     13 OCTOBER 1970
C
C     INITIALIZE CLOUD AND PARTICLE VARIABLES
      COMMON /SET1/
     1CAY         ,DETID(12) ,DIAM(200) ,DMEAN      ,DNS       ,EXPO
     2FMASS(200),IDISTR     ,IELEC      ,IRISE      ,ISIN      ,ISOUT
     3NDSTR       ,PS(200)   ,SD        ,SSAM       ,TME       ,TMP1
     4TMP2        ,PHI       ,USOIL     ,VPR        ,W         ,HEIGHT
     5ZSCL        ,NHODO     ,ZV(200)   ,VX(200)    ,VY(200)
      COMMON /CLOUD/
     1ALT(260)    ,ATP(260)  ,B0        ,CG(200)    ,CHANGE    ,CMLR
     2CX(10,90)   ,C2        ,C3        ,C6         ,DEK       ,DNID(12)
     3DRM         ,DS        ,DST       ,DSTO       ,DST1      ,DST2
     4DT          ,DU        ,DWT       ,DX         ,DZ        ,ED
     5EK          ,EPS       ,ES        ,ETA(260)   ,F         ,F.
     6GRV(260)    ,HLR       ,HOB       ,IPAM       ,IRAD      ,KCLD
     7KDI         ,KRX       ,KS        ,KSV        ,MCX       ,MWYA
     8N           ,NNN       ,NPVA      ,P          ,PRS(260)  ,PW
     9QI          ,R         ,RA        ,RFD        ,RHZ(260)  ,RL
     1RLH(260)    ,RM        ,RZT       ,S          ,SAVE      ,SLDTMP
     2SLM(260)    ,SMALLT    ,SZRO      ,T          ,TE        ,TMSD
     3U           ,V         ,VZRO      ,WT         ,X         ,XE
     4Y(200)      ,Z         ,ZBFR      ,ZBRSTZ     ,ZLMT
C
C
      DATA CHANGE,CMLR, DSTO,DST1,DS 2 ,   SMALLT ,  WT ,    N,MWYA
     1    / 100. , 0.0,.0625,0.5 ,5.0  ,    0.0   ,  0. ,    1,   1/
C
C
C
      DST=DSTO
      IF(W-0.55)20,21,21
   20 C2=0.075
      GO TO 22
   21 C2=0.065*W**(-.24)
   22 C3=0.175
      C6=1.0
C
      T=TMP1
C
C     COMPUTE INITIAL RISE VELOCITY
C
      O=0.409*W**0.071-1.0
      U=(243.*W**0.018)*(TME**O)
C
C     COMPUTE INITIAL TURBULENT KINETIC ENERGY DENSITY
C
      EK=0.5*U**2
C
C     COMPUTE FRACTION OF DETONATION ENERGY YIELD IN CLOUD
C     AT INITIAL TIME
C
      F=0.4406*W**0.01422
C
C     COMPUTE CLOUD CENTER HEIGHT, VOLUME, RADII, INITIAL MIXING RATIOS
```

```
C
      Z=HEIGHT+ZBRSTZ+108.*W**0.349
      CALL TRPL(Z,NPVA,ALT,ATP,TE)
      CALL TRPL(Z,NPVA,ALT,PRS,P)
      CALL TRPL(Z,NPVA,ALT,RLH,HLR)
      P=P*100.
      XE=109.98*HLR*(TE/273.)**(-5.13)*EXP((25.*(TE-273.))/TE)/(P*29.)
C
      TAD=0.
      IF(TMP2-848.)5,5,6
    5 TPR=TMP2
      GO TO 7
    6 TPR=848.
      TAD=1003.8*(TMP2-TPR)+0.06755*(TMP2**2-TPR**2)
    7 SOILHT=SSAM*(TAD+761.6*(TPR-TE)+0.2856*(TPR**2-TE**2)+
     11.881E+7*(1./TPR-1./TE))
      TAD=0.
      TPR=1
      IF(TPR-2300.)17,17,16
   16 TAD= -3587.5*(TPR-2300.) + 1.0625*(TPR**2-(2300.)**2)
      TPR=2300.
   17 FQ=4.18E12*F*W-SOILHT
      RMAO=PHI*FQ/(TAD+946.6*(TPR-TE)+0.09855*(TPR**2-TE**2)+XE*(1697.66
     1 *(T-TE) +0.572087*(T**2-TE**2)))
      RMWO=FQ*(1.-PHI)/(1697.66*(T-TE)+0.572087*(T**2-TE**2)+2.5E6)
     1  +RMAO*XE
      X=RMWO/RMAO
      V=(RMAO+RMWO)*287.*T*(1.+29.*X/18.)/(P*(1.+X))
      VZRO=V
      R=(3.*V/(12.5663706*0.66145))**(1.0/3.0)
      RZT=0.66145*R
      RM=RMAO+RMWO+SSAM
      S=SSAM/RMAO
      EPS=C3*(2.*EK)**1.5/RZT
C     COMPUTE PARAMETERS USED FOR VERTICAL CLOUD RADIUS COMPUTATIONS
C
      RL=0.092*W**0[illegible]
      BO=Z-RZT/RL
C
C     COMPUTE INITIAL IN-CLOUD PARTICLE CONCENTRATIONS
C
      Q=S/(1.0+X+S)*RM/(V*RFD*0.5235988)
      DO 801 J=1,NDSTR
      Y(J)=FMASS(J)*Q/PS(J)**3
  801 CG(J)=0.
      SZRO=S
      QI=0.5*(RM-SSAM)*T*(18.+29.*X)*(1.+XE)/(TE*(18.+29.*XE)*(1.+X))
      QI=QI*(1.+X)/(1.+X+S)
C     UPPER LIMIT FOR Z TO PREVENT PROGRAM RUNAWAY
C
      ZLMT=10000.0*W**0.25
      RETURN
      END
```

```
      SUBROUTINE CRM

       COMMON /SET/,
     1CAY        ,DETID(12) ,D AM(201) ,DMEAN     ,DNS      ,EXPO     ,
     2FMASS(200),IDISTR     ,IEXEC     ,IRISE     ,ISIN     ,ISOUT    ,
     3NOSTR      ,PS(200)   ,SD        ,SSAM      ,TME      ,TMP1     ,
     4TMP2       ,T2M       ,USOIL     ,VPR       ,W        ,HEIGHT   ,
     5ZSCL       ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)
       COMMON /CLOUD/
     1ALT(260)   ,ATP(260)  ,BO        ,CG(200)   ,CHANGE   ,CMER     ,
     2CX(10,90)  ,C2        ,C3        ,C6        ,DEK      ,DNID(12) ,
     3DRM        ,DS        ,DST       ,DST0      ,DST1     ,DST2     ,
     4DT         ,DU        ,DWI       ,DX        ,DZ       ,ED       ,
     5EK         ,EPS       ,ES        ,ETA(260)  ,F        ,FW       ,
     6GRV(260)   ,HER       ,HOB       ,IPAM      ,IRAD     ,KCLD     ,
     7KDI        ,KRX       ,KS        ,KSV       ,MCX      ,MWYA     ,
     8N          ,NNN       ,NPVA      ,P         ,PRS(260) ,PW       ,
     9QI         ,R         ,RA        ,RFD       ,RHZ(260) ,RL       ,
     1RLH(260)   ,RM        ,RZT       ,S         ,SAVE     ,SLDTMP   ,
     2SLM(260)   ,SMALLT    ,SZRO      ,T         ,TE       ,TMSD     ,
     3U          ,V         ,VZRO      ,WT        ,X        ,XE       ,
     4Y(200)     ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
C
  532 FORMAT('1',9X,'FRACTION OF THE DETONATION ENERGY YIELD IN THE CLOU
     1D AT INITIAL TIME IS',E12.5)
C
C     CALL CPV TO SET UP THE INITIAL CLOUD VARIABLES
C
      CALL CPV
C
      WRITE(ISOUT,532)F
C
C     COMPUTE THE PARTIAL PRESSURE OF THE WATER VAPOR IN THE CLOUD
C
   35 PW=P*X*29./(18.+29.*X)
C
C     COMPUTE SATURATION WATER VAPOR PRESSURE AND CLOUD AIR MASS
C
      ES=611.*(T/273.)**(-5.13)*EXP((25.*(T-273.))/T)
      RA=RM/V*(1.+X)/(1.+X+S+WT)
C
C     WET OR DRY EQUATIONS
C
      GO TO (150,1531,1531),N
  150 IF(ES-PW)152,152,1531
C
C     STORE VARIABLES(KSV=1) OR RESTART AT PREVIOUS TIME STEP (KSV=2)
C
  152 KSV=2
 1532 CALL RSTR
    9 VTEMPY=V
C
C     INTEGRATE
C
      CALL RKGILL
C
C         ADJUST IN CLOUD PARTICLE CONCENTRATIONS TO BE CONSISTENT WITH
```

```
C       CLOUD VOLUME CHANGE
C
        DO 86 J=1,NUSTR
   86   Y(J)=Y(J)*VTEMP/V
C
C       ACCUMULATE CLOUD TIME
C
        SMALLT=SMALLT+DST
C
C       TEST FOR TIME STEP CHANGE
        IF(ABS(SMALLT-1.0).LT.0.001)GO TO 87
        IF(SMALLT-1.0)8,87,88
   87   DST=DST1
   88   R=SQRT(3.*V/(RZI*12.5663706E0))
        GO TO 35
C
C       COMPUTE PARTICLE FALLOUT RATE
C
 1531   CALL CPFR
        GO TO (901,901,8),MWYA
  901   GO TO (1146,146),KCLD
  146   CALL DBG
 1146   CALL DCSN
    8   CALL CXPN
        GO TO (724,724,148),MWYA
  724   KSV=1
        GO TO 1532
  148   CALL CRMW
        RETURN
        END
```

```
      SUBROUTINE CRMW
C
C ****************************************************************
C
C     CRMW PRINTS SUMMARY OF OUTPUT OF THE CLOUD RISE MODULE.
C
C ****************************************************************
C
      COMMON /SET1/
     1CAY         ,DETID(12)  ,DIAM(201)  ,DMEAN      ,DNS        ,EXPO       ,
     2FMASS(200),IDISTR     ,ILACC      ,IRISE      ,ISIN       ,ISOUT      ,
     3NDSTR       ,PS(200)    ,SD         ,SSAM       ,TME        ,TMP1       ,
     4TMP2        ,T2M        ,USCIL      ,VPR        ,W          ,HEIGHT     ,
     5ZSCL        ,NHODO      ,ZV(200)    ,VX(200)    ,VY(200)
      COMMON /CLOUD/
     1ALT(260)    ,ATP(260)   ,B0         ,CG(200)    ,CHANGE     ,CMLR       ,
     2CX(10,90)   ,C2         ,C3         ,C6         ,DEK        ,DNID(12)   ,
     3DRM         ,DS         ,DST        ,DSTO       ,DST1       ,DST2       ,
     4DT          ,DU         ,DWT        ,DX         ,DZ         ,ED         ,
     5EK          ,EPS        ,ES         ,ETA(260)   ,F          ,FW         ,
     6GRV(260)    ,HLR        ,HOB        ,IPAM       ,IRAD       ,KCLD       ,
     7KDI         ,KRX        ,KS         ,KSV        ,MCX        ,MWYA       ,
     8N           ,NNN        ,NPVA       ,P          ,PRS(260)   ,PW         ,
     9QI          ,R          ,RA         ,RFD        ,RHZ(260)   ,RL         ,
     1RLH(260)    ,RM         ,RZT        ,S          ,SAVE       ,SLDTMP     ,
     2SLM(260)    ,SMALLT     ,SZRO       ,T          ,TE         ,TMSD       ,
     3U           ,V          ,VZRO       ,WT         ,X          ,XE         ,
     4Y(200)      ,Z          ,ZBFR       ,ZBRST2     ,ZLMT
C
C ****************************************************************
C
    3 FORMAT(//,10X,'PARAMETERS FOR THE LOGNORMAL PARTICLE DIAMETER-MASS
     1 FREQUENCY DISTRIBUTION'/10X,'GEOMETRIC MEAN =',E12.5,'MICROMETERS
     2',10X,'GEOMETRIC STANDARD DEVIATION =',E12.5)
  008 FORMAT (1H1 /////
     1   10X41HCLOUD RISE AND EXPANSION HISTORY TABLE CX//1X)
   20 FORMAT(
     1   49X19HCLOUD HISTORY TABLE,/
     1   5X5(3X5HCLOUD, 3X), 3X4HBASE, 8X3HTOP, 7X6HRADIAL,
     2   3X11HTEMPERATURE,4X, 3HGAS/
     3   8X4HTIME, 5X8HINTERVAL, 5X4HBASE, 8X3HTOP, 6X6HRADIUS,
     4   3X3(3X4HRATE, 4X), 14X, 7HDENSITY/
     5   5X2(3X5H(SEC), 3X), 3(4X3H(M), 4X), 3(2X7H(M/SEC), 2X),4X,
     6   3H(K),5X10H (KG/M**3)// (1X12, 1H), 1X, 1P10E11.4))
C
C ****************************************************************
C ****************************************************************
C
      WRITE(ISOUT,8)
      GO TO (1,2,2),IDISTR
    1 SIGMA=ALOG(SD)
      BARMU=ALOG(DMEAN)+3.*SIGMA**2
      EMU=EXP(BARMU)
      WRITE(ISOUT,3)EMU,SD
    2 WRITE(ISOUT,20)(J,(CX(I,J),I=1,10),J=1,MCX)
      RETURN
      END
```

```
      SUBROUTINE CXPN
C
C
C
C     CXPN TABULATES THE CLOUD RISE AND EXPANSION OUTPUT TABLE ARRAY CX
C     AND TESTS RATE OF RADIAL EXPANSION TO END CRM COMPUTATION. SEE 143
C
C
      COMMON /SET1/
     1CAY         ,DETID(12) ,DIAM(201) ,DMEAN       ,DNS         ,EXPO        ,
     2FMASS(200),IDISTR     ,IEXEC      ,IRISE       ,ISIN        ,ISOUT       ,
     3NDSTR       ,PS(200)    ,SD         ,SSAM        ,TME         ,TMP1        ,
     4TMP2        ,T2M        ,USOIL      ,VPR         ,W           ,HEIGHT      ,
     5ZSCL        ,NMODO      ,ZV(200)    ,VX(200)     ,VY(200)
      COMMON /CLOUD/
     1ALT(260)    ,ATP(260)   ,BO         ,CG( 30)     ,CHANGE      ,CMLR        ,
     2CX(10,90)   ,C2         ,C3         ,C6          ,DEK         ,DNID(12)    ,
     3DRM         ,DS         ,DST        ,D           ,DST1        ,DST2        ,
     4DT          ,DU         ,DWT        ,            ,DZ          ,ED          ,
     5EK          ,EPS        ,ES         ,      260)  ,F           ,FW          ,
     6GRV(260)    ,HLR        ,HOB             4      ,IRAD        ,KCLD        ,
     7KDI         ,KRX        ,KS              V      ,MCX         ,MWYA        ,
     8N           ,NNN        ,NPVA                   ,PRS(260)    ,PW          ,
     9QI          ,R          ,RA             PD      ,RHZ(260)    ,RL          ,
     1RLH(260)    ,RM         ,RZT             S      ,SAVE        ,SLDTMP      ,
     2SLM(260)    ,SMALLT     ,SZRO       ,T           ,TE          ,TMSD        ,
     3U           ,V          ,VZRO       ,WT          ,X           ,XE          ,
     4Y(200)      ,Z          ,ZBFR       ,ZBRSTZ      ,ZLMT
C
 5000 FORMAT(1H1, 9X, 46HCLOUD RISE IS TERMINATED IN CXPN AT STATEMENT 1
     14, 8H BY THE A6, 7H SWITCH///)
C
      DATA WORD1,WORD2/6HR RATE,6H MCX  /
C
C     PERFORM FIRST PASS INITIALIZATION
C
      GO TO (002, 020, 040), MWYA
  002 DO 004 MJ = 1, 90
      DO 004 MI = 1, 10
  004 CX (MI, MJ) = 0.0
      MCX = 1
      MWYA = 2
      DLTM = 0.0
      TSTM = SMALLT
      TSRD=EXP(0.014778*ALOG(W)-7.0499)
      ZBFR = Z
      GO TO 040
C
C     IS IT TIME TO RECORD CLOUD STATUS IN THE CX ARRAY
C        YES - TO 040
C        NO - TO 070
C
  020 IF (SMALLT - TSTM) 065, 040, 040
  040 CX (1, MCX) = SMALLT
      IF (Z - ZBFR) 041, 042, 042
  041 ZA = ZBFR
      GO TO 043
```

```
  042 ZA = Z
  043 CX (5, MCX) = R
      CX (9, MCX) = T
      CX(10,MCX)=RA
C                                         TEST TO END CRM COMPUTATION
      IF (MCX-5)343,343,143
  143 TSTR=ABS(ALOG(CX(5,MCX))-ALOG(CX(5,MCX-1)))
      TSTR = TSTR / (CX (1, MCX) - CX (1, MCX - 1))
      IF (TSTR - TSRD) 243, 343, 343
  243 MWYA = 3
      NSTAT=243
      WRITE(ISOUT,5000)NSTAT,WORD1
  343 CX (3, MCX) = ZA - RZT
      CX (4, MCX) = ZA + RZT
  060 MCX = MCX + 1
C                                         CHECK CAPACITY OF ARRAY CX
      IF (MCX - 90) 062, 062, 061
  061 MWYA = 3
      NSTAT=61
      WRITE(ISOUT,5000)NSTAT,WORD2
  062 CXM = MCX
C
C     COMPUTE THE TIME AT WHICH THE NEXT CX ARRAY ENTRIES ARE TO BE MADE
C
      DLTM = DLTM + CXM * .084946
      TSTM = TSTM + DLTM
  065 IF (Z - ZBFR) 068, 068, 067
  067 ZBFR = Z
  068 GO TO (070, 070, 100), MWYA
  070 RETURN
C                                         COMPLETE OUTPUT CX TABLE
  100 MCX = MCX - 1
      IF (CX (1, MCX - 1) - CX (1, MCX)) 102, 100, 102
  102 DO 104 MK = 2, MCX
C                                         COMPUTE TIME INTERVAL LENGTH
      CX (2, MK - 1) = CX (1, MK) - CX (1, MK - 1)
C                                         COMPUTE VERTICAL RATES
      CX (6, MK - 1) = (CX (3, MK) - CX (3, MK - 1)) / CX (2, MK - 1)
      CX (7, MK-1) = (CX (4, MK) - CX(4, MK-1)) / CX (2, MK - 1)
C                                         COMPUTE RADIAL RATE
  104 CX (8, MK - 1) = (CX (5, MK) - CX (5, MK - 1)) / CX (2, MK - 1)
      DO 106 ML = 1, MCX
  106 CX (1, ML) = CX (1, ML) + TME
      GO TO 070
      END
```

```
      SUBROUTINE DBG
      COMMON /SET1/
     1CAY        ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,
     2FMASS(200),IDISTR    ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,
     3NDSTR      ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,
     4TMP2       ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,
     5ZSCL       ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)
      COMMON /CLOUD/
     1ALT(260)   ,ATP(260)  ,BU        ,CG(200)   ,CHANGE    ,CMLR      ,
     2CX(10,90)  ,C2        ,C3        ,C6        ,DEK       ,DNID(12)  ,
     3DRM        ,DS        ,DST       ,DSTO      ,DST1      ,DST2      ,
     4DT         ,DU        ,DWT       ,DX        ,DZ        ,ED        ,
     5EK         ,EPS       ,ES        ,ETA(260)  ,F         ,FW        ,
     6GRV(260)   ,HLR       ,HOB       ,IPAM      ,IRAD      ,KCLD      ,
     7KDI        ,KRX       ,KS        ,KSV       ,MCX       ,MWYA      ,
     8N          ,NNN       ,NPVA      ,P         ,PRS(260)  ,PW        ,
     9QI         ,R         ,RA        ,RFD       ,RHZ(260)  ,RL        ,
     1RLH(260)   ,RM        ,RZT       ,S         ,SAVE      ,SLDTMP    ,
     2SLM(260)   ,SMALLT    ,SZRO      ,T         ,TE        ,TMSD      ,
     3U          ,V         ,VZRO      ,WT        ,X         ,XE        ,
     4Y(200)     ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
C
C *******************************************************************
C
C     DBG IS DEBUG PRINTER
C
C *******************************************************************
C
C
C *******************************************************************
C
  016 FORMAT (1H0 /
     1  3X1P9E13.4 /
     2  (10X1H*, 5X8E13.4))
   17 FORMAT(21X,'PS',11X,'CG',11X,'Y',11X,'PS',11X,'CG',11X,'Y'/16X,1P6
     1E13.4)
  099 FORMAT (1H0 / 49X17HCLOUD DEBUG PRINT //
     1  9X2HST, 11X1HU, 12X1HX, 12X1HT, 12X1HR, 12X1HZ, 12X2HEK,
     2  11X1HV, 12X2HWT / 10X1H*, 11X2HTE, 11X2HRM, 11X2HES,
     3  11X1HP, 12X2HPW, 11X2HED, 10X3HRLH, 11X1HS/
     4  10X1H*, 10X3HEPS, 10X3HRZT , 9X4HCMLR,///)
C
C *******************************************************************
C *******************************************************************
C
      IF (AMOD (SMALLT, 13.0)) 2146, 1149, 2146
 1149 WRITE(ISOUT,99)
 2146 IF (SMALLT) 1146, 1146, 3146
 3146 IF(SMALLT-AINT(SMALLT))149,4146,149
 4146 IF(AMOD(SMALLT,2.0))1146,149,1146
 1146 WRITE(ISOUT,16)
     1  SMALLT, U, X, T, R, Z, EK, V, WT,
     2  TE, RM, ES, P, PW, ED, HLR, S,
     3  EPS, RZT , CMLR
      WRITE(ISOUT,17)
     1  (PS  (I), CG (I), Y (I),
     2  PS  (I + 1), CG (I + 1), Y (I + 1),
```

```
    3 I=1,NDSTR,2)                                                    DBG  058
  149 RETURN                                                          DBG  059
      END                                                             DBG  060
```

```
      SUBROUTINE DCSN
      COMMON /SET1/
     1CAY        ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,
     2FMASS(200),IDISTR    ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,
     3NDSTR      ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,
     4TMP2       ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,
     5ZSCL       ,NHODC     ,ZV(200)   ,VX(200)   ,VY(200)
      COMMON /CLOUD/
     1ALT(260)   ,ATP(260)  ,B0        ,CG(200)   ,CHANGE    ,CMLR      ,
     2CX(10,90)  ,C2        ,C3        ,C6        ,DEK       ,DNID(12)  ,
     3DRM        ,DS        ,DST       ,DSTO      ,DST1      ,DST2      ,
     4DT         ,DU        ,DWT       ,DX        ,DZ        ,ED        ,
     5EK         ,EPS       ,ES        ,ETA(260)  ,F         ,FW        ,
     6GRV(260)   ,HLR       ,HOB       ,IPAM      ,IRAD      ,KCLD      ,
     7KDI        ,KRX       ,KS        ,KSV       ,MCX       ,MWYA      ,
     8N          ,NNN       ,NPVA      ,P         ,PRS(260)  ,PW        ,
     9QI         ,R         ,RA        ,RFD       ,RHZ(260)  ,RL        ,
     1RLH(260)   ,RM        ,RZT       ,S         ,SAVE      ,SLDTMP    ,
     2SLM(260)   ,SMALLT    ,SZRO      ,T         ,TE        ,TMSD      ,
     3U          ,V         ,VZRO      ,WT        ,X         ,XE        ,
     4Y(200)     ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
C
C ***********************************************************************
C
C     DCSN DETERMINES AT THE END OF EACH TIME STEP WHETHER TO
C     CONTINUE THE CRM COMPUTATION
C
C ***********************************************************************
C
  066 FORMAT(14HOSWITCH TO DRY)
  077  FORMAT(14HOSWITCH TO WET)
  088 FORMAT(1H1, 9X, 46HCLOUD RISE IS TERMINATED IN DCSN AT STATEMENT 1
     14, 8H BY THE A6, 7H SWITCH///)
C
      DATA WORD1,      WORD3,WORD4 /6H TEMP ,        6H ZLMT ,6HR.LT.1/
C
C ***********************************************************************
C ***********************************************************************
C
      GO TO (151,154,1531),N
C
C      SHOULD WE SWITCH TO WET MODE---
C             YES-- TO 041
C
 1531 IF(ES-PW)041,041,008
C
  041  N=2
      GO TO (151, 1041), KCLD
 1041 WRITE(ISOUT,77)
       GO TO 151
C
C 154 SHOULD WE SWITCH TO DRY MODE-
C       NO TO 151
C
  154 IF(ES-PW.LE.0.0) GO TO 151
      N=1
      GO TO(151,152),KCLD
```

```
  152 WRITE(ISOUT,66)
C
C     TEST FOR TIME STEP CHANGE
C
  151 IF (SMALLT - CHANGE) 014, 015, 015
  015  DST=DST2
C
C     TEST FOR ANOMALOUS CLOUD RISE AND SET UP TERMINATION CONDITION IF
C     ANOMALY IS FOUND
C
C
C     TEST FOR TEMPERATURE ANOMALY
C
  014 IF(ABS(T)-10.)114,20,20
  114 NSTAT=14
      WORD=WORD1
      GO TO 1
C
C     TEST FOR R.LT.1 ANOMALY
C
  020  IF(R-1.) 120,13,13
  120 NSTAT=20
      WORD=WORD4
      GO TO 1
C
C     TEST FOR ZLMT ANOMALY
C
  013 IF (Z - ZLMT) 008, 008, 113
  113 NSTAT=13
      WORD=WORD3
C                                                  COMPLETE CX TABLE
  001 MWYA = 3
      WRITE(ISOUT,88) NSTAT,WORD
  008 RETURN
      END
```

```
      SUBROUTINE DERIV
C
C     20 AUGUST 1969
      COMMON /SET1/
     1CAY        ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,
     2FMASS(200),IDISTR     ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,
     3NDSTR      ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,
     4TMP2       ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,
     5ZSCL       ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)
      COMMON /CLOUD/
     1ALT(260)   ,ATP(260)  ,B0        ,CG(200)   ,CHANGE    ,CMLR      ,
     2CX(10,90)  ,C2        ,C3        ,C6        ,DEK       ,DNID(12)  ,
     3DRM        ,DS        ,DST       ,DST0      ,DST1      ,DST2      ,
     4DT         ,DU        ,DWT       ,DX        ,DZ        ,ED        ,
     5EK         ,EPS       ,ES        ,ETA(260)  ,F         ,FW        ,
     6GRV(260)   ,HLR       ,HOB       ,IPAM      ,IRAD      ,KCLD      ,
     7KDI        ,KRX       ,KS        ,KSV       ,MCX       ,MWYA      ,
     8N          ,NNN       ,NPVA      ,P         ,PRS(260)  ,PW        ,
     9QI         ,R         ,RA        ,RFD       ,RHZ(260)  ,RL        ,
     1RLH(260)   ,RM        ,RZT       ,S         ,SAVE      ,SLDTMP    ,
     2SLM(260)   ,SMALLT    ,SZRO      ,T         ,TE        ,TMSD      ,
     3U          ,V         ,VZRO      ,WT        ,X         ,XE        ,
     4Y(200)     ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
C
C
      DZ=0
C
C
C     OBTAIN VALUES OF AMBIENT TEMPERATURE, PRESSURE ,RELATIVE HUMIDITY
C
      CALL TRPL(Z,NPVA,ALT,ATP,TE)
      CALL TRPL(Z,NPVA,ALT,PRS,P)
      CALL TRPL(Z,NPVA,ALT,RLH,HLR)
      P=P*100.
C
C
C     COMPUTE AMBIENT AIR WATER MIXING RATIO
C
      XE=109.98*HLR*(TE/273.)**(-5.13)*EXP((25.*(TE-273.))/TE)/(P*29.)
      TAD=0.
C
C     COMPUTE SPECIFIC HEAT OF IN-CLOUD AIR
C
      IF(T-2300.)15,15,16
   15 TPR=T
      CP=946.6+0.1971*T
      GO TO 17
   16 TPR=2300.
      TAD=-3587.5*(T-TPR)+1.0625*(T**2-TPR**2)
      CP=-3587.5+2.125*T
   17 CP=(CP+X*(1697.66+1.144174*T))/(1.+X)
      CPAI=TAD+946.6*(TPR-TE)+0.09855*(TPR**2-TE**2)
C
C     COMPUTE SPECIFIC HEAT OF IN-CLOUD AIR-WATER-SOIL MIXTURE
C
      RMIX=(1.+X)/(1.+X+S+W)
      CR=CP*RMIX
```

```
      IF(TMP2-T)380,381,381
  381 IF(T-848.)3810,3810,3811
 3810 CS=781.6+0.5612*T-1.881E7/T**2
      GO TO 3812
 3811 CS=1003.8+0.13510*T
 3812 CR=CR+CS*(S+WT)/(1.+X+S+WT)
  380 QXE=(1.+XE)/(1.+29.*XE/18.)
      QX=(1.+29.*X/18.)/(1.+X)
      QT=T/TE
C
C     COMPUTE HORIZONTAL RADIUS OF CLOUD
C
      R=SQRT(3.*V/(RZT*12.5663706E0))
C
C     IS CLOUD CENTER ALTITUDE GREATER OR LESS THAN ALTITUDE OF PREVIOUS
C     TIME STEP
C        GREATER- TO 1101
C        LESS - TO 1100
      IF(KS.GT.0)GO TO 1102
      IF(Z-ZBFR)1100,1101,1101
 1100 DZ=0.
      U=0.
      DU=0.
      NNN=2
      GO TO 1102
 1101 NNN=1
C
C     COMPUTE CLOUD S TO VOLUME RATIO
C
 1102 SV=12.5663706*R**2/V
C
C     COMPUTE TURBULENT KINETIC ENERGY DISSIPATION RATE
C
      EPS=C3*(2.*EK)**1.5/RZT
      Q7=AMAX1(ABS(U),SQRT(2.*EK))
      QQ=QT*QX*QXE*(1.+X+WT)/(1.+X+S+WT)
      IF(NHODO)1103,1103,1104
 1103 VS=0.0
      GO TO 1105
C
C     COMPUTE WIND SHEAR CORRECTION FACTOR
C
 1104 ZTP=Z+RZT
      ZBT=Z-RZT
      CALL TRPL(ZTP,NHODO,ZV,VX,VXT)
      CALL TRPL(ZTP,NHODO,ZV,VY,VYT)
      CALL TRPL(ZBT,NHODO,ZV,VX,VXB)
      CALL TRPL(ZBT,NHODO,ZV,VY,VYB)
      VS=SQRT((VXT-VXB)**2 + (VYT-VYB)**2)
 1105 RS=SV*Q7+1.5*C6*VS/R
      GO TO (100,101,100),N
C
C     DRY EQUATIONS
C
C
C     COMPUTE AIR ENTRAINMENT RATE
C
```

```
100 DRM=(RM/(1.-CPAI/(CP*T*QX)))*RMIX*(RS   *RL+(QT*QX*QXE*9.8*U-EPS)*
   1RMIX/(CR*T*QX)-9.8*U/(287./QXE*TE))
    DRME=DRM
C
C     SUBTRACT AWAY RATE OF MASS LOST DUE TO PARTICLES FALLING OUT CLOUD
C     BOTTOM DURING RISE
C
      DRM=DRM-CMLR
C
C     COMPUTE TIME DERIVATIVE OF WATER VAPOR MIXING RATIO
C
      DX=-(1.+X+S)/(1.+XE)*(X-XE)*DRME/RM
C
C     COMPUTE TIME DERIVATIVE OF CLOUD TEMPERATURE
C
      DT=-(RMIX*(QT*QX*QXE*9.8*U-EPS)+CPAI*DRME/RM)/CR
      WT=0.
C
C     NO CHANGE IN LIQUID WATER MIXING RATIO
C
      DWT=0.
      GO TO 555
C
C     WET EQUATIONS
C
  101 Q1=1.+X*29./18.
      IF(T-273.)102,103,103
  102 CL=2.83E6
      GO TO 104
  103 CL=2.5E6
  104 Q2=CL*X/(287.*T)
      Q3=18.*Q2/29./T
      Q4=1.+Q2
      Q5=1.+CL*Q3/CP
      Q6=CL*(X-XE)/CP+T-TE
      Q9=RMIX/Q5
      Q8=Q9/T/QX
C
C     COMPUTE AIR ENTRAINMENT RATE
C
      DRM=RMIX*(RM/(1.0-Q6*Q8))*(RS*RL+(QX*QT*9.8*Q4*U*QXE-EPS)/CP/T/QX*
     1Q9-(9.8*U)/(287./QXE*TE))
      DRME=DRM
C
C     SUBTRACT AWAY RATE OF MASS LOST DUE TO PARTICLES FALLING OUT CLOUD
C     BOTTOM DURING RISE
C
      DRM=DRM-CMLR
C
C     COMPUTE TIME DERIVATIVE OF TEMPERATURE
C
      DT=((-QX*QT*Q4*9.8*U/CP*QXE-Q6*DRME/(RMIX*RM))+EPS/CP)*Q9
C
C     COMPUTE TIME DERIVATIVE OF WATER VAPOR MIXING RATIO
C
      DX=Q1*(Q3*DT+9.8*X*U/(287.*TE)*QXE)
C
```

```
C     COMPUTE TIME DERIVATIVE OF LIQUID WATER MIXING RATIO
C
      DWT=-(1.+X+S+WT)/RM*((WT+X-XE)/(1.+XE)*DRME+WT*CMLR/(S+WT))-DX
C
  555 ED1= 2.*C2*U7*UU/R21
      GO TO (621,1110),NNN
  621 OMU=1.-RL
C
C     COMPUTE CLOUD VERTICAL ACCELERATION
C
      DU=(9.8/OMU*(QT*QX*QXE*RMIX-1.)-(OMU*ED1     +DRM/RM)*U)*RM/(RM+QI)
C     COMPUTE EDDY VISCOUS RATE OF LOSS OF KINETIC ENERGY OF RISE
C
 1110 ED=ED1*U**2
C     COMPUTE TIME DERIVATIVE OF TURBULENT KINETIC ENERGY DENSITY
C
      DEK=ED-(EK-0.5*U**2)*DRME/RM-EPS
C
C     COMPUTE TIME DERIVATIVE OF SOIL MIXING RATIO
C
      DS=-(1.+X+S+WT)*S/RM*(CMLR/(S+WT)+DRME/(1.+XE))
C
C     COMPUTE IN-CLOUD GAS DENSITY
C
      RA=RM/V*RMIX
      IF(EPS)902,902,901
  902 EPS=1.0E-4
  901 RETURN
      END
```

```
      SUBROUTINE ICRD
C
C     13 OCTOBER 1970
C
C *********************************************************************
C
      COMMON /SET1/
     1CAY       ,DETAID(12) ,DIAM(201)  ,DMEAN      ,DNS        ,EXPO
     2FMASS(200),IDISTR     ,IEACC      ,IRISE      ,ISIN       ,ISOUT
     3NDSTR     ,PS(200)    ,SD         ,SSAM       ,TME        ,TMP1
     4TMP2      ,PHI        ,DSC        ,VPR        ,W          ,HEIGHT
     5ZSCL      ,NPCDO      ,ZV(200)    ,VX(200)    ,VY(200)
      COMMON /CLOUD/
     1ALT(260)  ,ATP(260)   ,BU         ,CG(200)    ,CHANGE     ,CMLR
     2CX(10,90) ,C2         ,C3         ,C6         ,DEK        ,DNID(12)
     3DRM       ,DS         ,DST        ,DST0       ,DST1       ,DST2
     4DT        ,DU         ,DWT        ,DX         ,DZ         ,ED
     5EK        ,EPS        ,ES         ,ETA(260)   ,F          ,FW
     6GRV(260)  ,HLR        ,HOB        ,IPAM       ,IRAD       ,KCLD
     7KDI       ,KRX        ,KS         ,KSV        ,MCX        ,MWYA
     8N         ,NNN        ,NPVA       ,P          ,PRS(260)   ,PW
     9QI        ,R          ,RA         ,RFD        ,RHZ(260)   ,RL
     1RLH(260)  ,RM         ,RZT        ,S          ,SAVE       ,SLDTMP
     2SLM(260)  ,SMALLT     ,SZRO       ,T          ,TE         ,TMSD
     3U         ,V          ,VZRO       ,WT         ,X          ,XE
     4Y(200)    ,Z          ,ZBFR       ,ZBRSTZ     ,ZLMT
C
      DIMENSION ATID(12)
C *********************************************************************
C *********************************************************************
C     CONTROL PARAMETER GLOSSARY
C
C       KDI    NUMBER OF WAFERS PER PARTICLE SIZE CLASS (RSXP)
C       IRAD   WAFER SUBDIVISION FACTOR (RSXP)
C       KCLD   CRM DEBUG PRINTOUT CONTROL
C       KRX    RSXP DEBUG PRINTOUT CONTROL
C       IPAM   PARTICLE ACTIVITY CALCULATION CONTROL (ALWAYS ZERO)
C       KATM   ATMOSPHERE TABLE PRINTOUT CONTROL
C      (NDSTR  NUMBER OF PARTICLE SIZE CLASSES)
C      (IDISTR PARTICLE DISTRIBUTION FORM CONTROL)
C
C *********************************************************************
C
 1000 FORMAT(1H1,///51X19H* * * * * * * * * *//12X101HT H E   D E P A R
     1T M E N T   O F   D E F E N S E   F A L L O U T   P R E D I C T I
     2O N   S Y S T E M,//51X,19H* * * * * * * * * *////52X,17HCLOUD-RIS
     3E MODULE///55X,11HPREPARED BY/
     4 42X,37HNAVAL RADIOLOGICAL DEFENSE LABORATORY/ 55X,11HS.F.,CALIF./
     5 58X,3HAND/ 53X,17HARCON CORPORATION/53X,16HWAKEFIELD, MASS.////)
 1100 FORMAT(12A6)
 1200 FORMAT(6I4)
 1300 FORMAT(E12.5)
 1400 FORMAT(20X,'CLOUD RISE RUN IDENTIFICATION = ',12A6//20X,'ATMOSPHER
     1E IDENTIFICATION      =',12A6//20X,'ELEVATION OF GROUND ZERO = ',F
     28.1,' METERS'/20X,'SOIL SOLIDIFICATION TEMPERATURE = ',F8.1,' DEGR
     3EES KELVIN'/20X,'PARTICLE DENSITY (C.G.S.) = ',F8.4/20X,'YIELDS (K
     4T) ='/23X,'TOTAL = ',E11.4,3X,'FISSION = ',E11.4/20X,'FRACTION OF
```

```
     5AVAILABLE ENERGY USED TO HEAT AIR INITIALLY = 'E11.4)            ICRD 058
 1500 FORMAT(20X,'COMPUTATION CONTROL INPUTS-'/20X,'  NDSTR IDISTR    KDICRD 059
     1I   IRAD    KCLD    KRX    IPAM    KATM'/20X,8I7////)             ICRD 060
 1600 FORMAT(20X,'FRACTION OF AVAILABLE ENERGY USED TO HEAT LIQUID WATERICRD 061
     1 INITIALLY = 'E11.4////)                                          ICRD 062
 1700 FORMAT(20X,       22HCOMPUTATION CONTROLS -/23X,                  ICRD 063
     1                                     44HNUMBER OF PARTICLE SIZICRD 064
     2E CLASSES REQUESTED = I4/23X, 54HNUMBER OF CLOUD SUBDIVISIONS(WAFEICRD 065
     3RS) PER SIZE CLASS = I4/                                          ICRD 066
     4                  23X, 27HWAFER SUBDIVISION FACTOR = I4)          ICRD 067
  998 FORMAT(1H1,                                                       ICRD 068
     1            50X,10HATMOSPHERE,51X///7X,3HALT,11X,3HATP,11X,3HRHZ,11X,3ICRD 069
     2HETA,11X,3HPRS,11X,3HORV,11X,3HSLM,11X,3HRLH)                     ICRD 070
  999 FORMAT(//(8(2X,E12.5)))                                           ICRD 071
C                                                                       ICRD 072
C **********************************************************************ICRD 073
C **********************************************************************ICRD 074
C                                                                       ICRD 075
C                                                                       ICRD 076
C **********************************************************************ICRD 077
C                                                                       ICRD 078
C   SEQUENCE OF INPUTS                                                  ICRD 079
C                                                                       ICRD 080
C   1  READ CLOUD RISE IDENTIFICATION                                   ICRD 081
C   2  READ CONTROL CARD                                                ICRD 082
C   3  READ GZ ELEVATION (METERS)                                       ICRD 083
C   4  READ SOIL SOLIDIFICATION TEMPERATURE (DEGREES KELVIN)            ICRD 084
C   5  READ FISSION YIELD    (KT)                                       ICRD 085
C   6  READ FRACTION OF ENERGY AVAILABLE IN THE CLOUD USED TO HEAT AIR  ICRD 086
C   7  READ ATMOSPHERE IDENTIFICATION                                   ICRD 087
C                                                                       ICRD 088
C **********************************************************************ICRD 089
C                                                                       ICRD 090
      READ(ISIN,1100)DNID                                               ICRD 091
      READ(ISIN,1200)KDI,IRAD,KCLD,KRX,IPAM,KATM                        ICRD 092
      READ(ISIN,1300)ZBRSTZ                                             ICRD 093
      READ(ISIN,1300)SLDTMP                                             ICRD 094
      READ(ISIN,1300)FW                                                 ICRD 095
      READ(ISIN,1300)PHI                                                ICRD 096
      READ(ISIN,1100)ATID                                               ICRD 097
C                                                                       ICRD 098
      CALL ATMR                                                         ICRD 099
C                                                                       ICRD 100
C **********************************************************************ICRD 101
C                                                                       ICRD 102
C   SEQUENCE OF OUTPUTS                                                 ICRD 103
C                                                                       ICRD 104
C   1  WRITE CLOUD RISE MODULE HEADING                                  ICRD 105
C   2  WRITE INPUT DATA                                                 ICRD 106
C   3  WRITE COMPUTATION CONTROLS                                       ICRD 107
C   4  WRITE CRM COMPUTATION CONTROLS                                   ICRD 108
C   5  WRITE RSAP COMPUTATION CONTROLS                                  ICRD 109
C   6  WRITE ATMOSPHERE PROPERTIES                                      ICRD 110
C                                                                       ICRD 111
C **********************************************************************ICRD 112
C                                                                       ICRD 113
      RPHI=1.0-PHI                                                      ICRD 114
```

```
      WRITE(ISOUT,1300)                                                 ICRD 115
      WRITE(ISOUT,1400)DATE,ATID,ZBRSTZ,SLDIMP,DNS,W,FW,PHI             ICRD 116
      WRITE(ISOUT,1600)RPHI                                             ICRD 117
      WRITE(ISOUT,1500)NDSTR,IDISTR,KDI,IRAD,KCLD,KRX,IPAM,KATM         ICRD 118
      WRITE(ISOUT,1700)NDSTR,KDI,IRAD                                   ICRD 119
      IF(KATM)2,2,1                                                     ICRD 120
    1 WRITE(ISOUT,998)                                                  ICRD 121
      WRITE(ISOUT,999)(ALT(I),ATP(I),RH2(I),ETA(I),PRS(I),GRV(I),SLM(I),ICRD 122
     1RLH(I),I=1,NPVA)                                                  ICRD 123
    2 KCLD = KCLD + 1                                                   ICRD 124
      KRX = KRX + 1                                                     ICRD 125
      RETURN                                                            ICRD 126
      END                                                               ICRD 127
```

```
      SUBROUTINE RKGILL
C
C     18 AUGUST 1969
      COMMON /SET1/
     1CAY        ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,
     2FMASS(200),IDISTR    ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,
     3NDSTR      ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,
     4TMP2       ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,
     5ZSCL       ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)
      COMMON /CLOUD/
     1ALT(260)   ,ATP(260)  ,BO        ,CG(200)   ,CHANGE    ,CMLR      ,
     2CX(10,90)  ,C2        ,C3        ,C6        ,DEK       ,DNID(12)  ,
     3DRM        ,DS        ,DST       ,DSTO      ,DST1      ,DST2      ,
     4DT         ,DU        ,DWT       ,DX        ,DZ        ,ED        ,
     5EK         ,EPS       ,ES        ,ETA(260)  ,F         ,FW        ,
     6GRV(260)   ,HLR       ,HOB       ,IPAM      ,IRAD      ,KCLD      ,
     7KDI        ,KRX       ,KS        ,KSV       ,MCX       ,MWYA      ,
     8N          ,NNN       ,NPVA      ,P         ,PRS(260)  ,PW        ,
     9QI         ,R         ,RA        ,RFD       ,RHZ(260)  ,RL        ,
     1RLH(260)   ,RM        ,RZT       ,S         ,SAVE      ,SLDTMP    ,
     2SLM(260)   ,SMALLT    ,SZRO      ,T         ,TE        ,TMSD      ,
     3U          ,V         ,VZRO      ,WT        ,X         ,XE        ,
     4Y(200)     ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
C
C
      DIMENSION DVBL(8),VBL(8),RKG(8)
      H=DST
      KS  =0
      KYCL=1
C
      VBL(1)=WT
      VBL(2)=RM
      VBL(3)=U
      VBL(4)=X
      VBL(5)=T
      VBL(6)=Z
      VBL(7)=EK
      VBL(8)=S
C
   20 CALL DERIV
      IF(U.EQ.0.0) VBL(3)=0.
      DVBL(1)=DWT
      DVBL(2)=DRM
      DVBL(3)=DU
      DVBL(4)=DX
      DVBL(5)=DT
      DVBL(6)=DZ
      DVBL(7)=DEK
      DVBL(8)=DS
C
      KS=KS+1
      GO TO (1,3,5,7),KS
C
    1 DO 2 J=1,8
      VBL(J)=VBL(J)+0.5*H*DVBL(J)
    2 RKG(J)=DVBL(J)
      GO TO 10
```

```
    3 DO 4 J=1,8
      VBL(J)=VBL(J)+.29289322*H*(DVBL(J)-RKG(J))
    4 RKG(J)=.58578644*DVBL(J)+.12132034*RKG(J)
      GO TO 10
    5 DO 6 J=1,8
      VBL(J)=VBL(J)+1.7071068*H*(DVBL(J)-RKG(J))
    6 RKG(J)=3.4142136*DVBL(J)-4.1213203*RKG(J)
      GO TO 10
    7 DO 8 J=1,8
    8 VBL(J)=VBL(J)+.16666667*H*(DVBL(J)-2.*RKG(J))
C
      KYCL=2
   10 W1=VBL(1)
      RM=VBL(2)
      U=VBL(3)
      X=VBL(4)
      T=VBL(5)
      Z=VBL(6)
      EK=VBL(7)
      S=VBL(8)
      RZT=RL*(Z-BO)
      CALL TRPL(Z,NPVA,ALT,PRS,PQR)
      V=2.87*T*RM*(1.+X)/PQR/(1.+X+S+WT)*(1.0+X*29./18.)/(1.0+X)
      GO TO(20,30),KYCL
   30 RETURN
      END
```

```
      SUBROUTINE RSTR
C
C     20 AUGUST 1969
C
C     RSTR PRESERVES AND/OR RESTORES CRM VARIABLES
C
      COMMON /SET1/
     1CAY      ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,
     2FMASS(200),IDISTR   ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,
     3NDSTR    ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,
     4TMP2     ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,
     5ZSCL     ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)
      COMMON /CLOUD/
     1ALT(260) ,ATP(260)  ,BO        ,CG(200)   ,CHANGE    ,CMLR      ,
     2CX(10,90) ,C2       ,C3        ,C6        ,DEK       ,DNID(12)  ,
     3DRM      ,DS        ,DST       ,DSTO      ,DST1      ,DST2      ,
     4DT       ,DU        ,DWT       ,DX        ,DZ        ,ED        ,
     5EK       ,EPS       ,ES        ,ETA(260)  ,F         ,FW        ,
     6GRV(260) ,HLR       ,HOB       ,IPAM      ,IRAD      ,KCLD      ,
     7KDI      ,KRX       ,KS        ,KSV       ,MCX       ,MWYA      ,
     8N        ,NNN       ,NPVA      ,P         ,PRS(260)  ,PW        ,
     9QI       ,R         ,RA        ,RFD       ,RHZ(260)  ,RL        ,
     1RLH(260) ,RM        ,RZT       ,S         ,SAVE      ,SLDTMP    ,
     2SLM(260) ,SMALLT    ,SZRO      ,T         ,TE        ,TMSD      ,
     3U        ,V         ,VZRO      ,WT        ,X         ,XE        ,
     4Y(200)   ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
C
C
      DIMENSION PY(210)
C
      GO TO(1,3),KSV
    1 PEK=EK
      PRM=RM
      PSS=S
      PT=T
      PU=U
      PV=V
      PWT=WT
      PX=X
      PZ=Z
      PRZT=RZT
      DO 2 NP=1,NDSTR
    2 PY(NP)=Y(NP)
      GO TO 5
C
    3 SMALLT=SMALLT-DST
      DST=0.5
      EK=PEK
      RM=PRM
      S=PSS
      T=PT
      U=PU
      V=PV
      WT=PWT
      X=PX
      Z=PZ
      RZT=PRZT
```

```
      DO 4 NP=1,NDSTR
    4 Y(NP)=PY(NP)
      N=3
    5 RETURN
      END
```

```
      SUBROUTINE RSXP
C
      COMMON /SET1/
     1CAY      ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,
     2FMASS(200),IDISTR    ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,
     3NDSTR    ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,
     4TMP2     ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,
     5ZSCL     ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)
      COMMON /CLOUD/
     1ALT(260) ,ATP(260)  ,B0        ,CG(200)   ,CHANGE    ,CMLR      ,
     2CX(10,90),C2        ,C3        ,C6        ,DEK       ,DNID(12)  ,
     3DRM      ,DS        ,DST       ,DSTO      ,DST1      ,DST2      ,
     4DT       ,DU        ,DWT       ,DX        ,DZ        ,ED        ,
     5EK       ,EPS       ,ES        ,ETA(260)  ,F         ,FW        ,
     6GRV(260) ,HLR       ,HOB       ,IPAM      ,IRAD      ,KCLD      ,
     7KDI      ,KRX       ,KS        ,KSV       ,MCX       ,MWYA      ,
     8N        ,NNN       ,NPVA      ,P         ,PRS(260)  ,PW        ,
     9QI       ,R         ,RA        ,RFD       ,RHZ(260)  ,RL        ,
     1RLH(260) ,RM        ,RZT       ,S         ,SAVE      ,SLDTMP    ,
     2SLM(260) ,SMALLT    ,SZRO      ,T         ,TE        ,TMSD      ,
     3U        ,V         ,VZRO      ,WT        ,X         ,XE        ,
     4Y(200)   ,Z         ,ZBFR      ,ZBRSTZ    ,ZLMT
C
      DIMENSION DPST(8,2),DPX(2,90),VISCX(90),GDPST(10,100),PPST(8,10)
C
C
C     DPST(1,MBT)  TIME
C     DPST(2,MBT)  ALTITUDE OF INCREMENT CENTER OF MASS
C     DPST(3,MBT)  RADIUS
C     DPST(4,MBT)  PARTICLE DIAMETER MICROMETERS
C     DPST(5,MBT)  MASS
C     DPST(6,MBT)  INCREMENT THICKNESS
C     DPST(7,MBT)  ALTITUDE OF INCREMENT BOTTOM
C     DPST(8,MBT)  INCREMENT VOLUME
C
  444 FORMAT('1'/10X,'DEPOSIT INCREMENTS'//15X,'TIME',7X,'ALT',8X,'RAD',
     17X,'DIAM',8X,'MASS',8X,'DZ',7X,'ZLOW',7X,'VOL'//)
  666 FORMAT(1X,1PE11.3,7E11.3,I2,5X,I2,'IN CLOUD')
  777 FORMAT(1X,1PE11.3,7E11.3,I2,5X,I2)
  888 FORMAT(1X,1PE11.3,7E11.3/1X,'SUBDIVISION',2X,I5,5X,'SIZE CLASS',2X
     1,I5/)
  758 FORMAT(//'DAVIES EQUATIONS ARE INACCURATE FOR',F12.3,' MICRONS AT'
     1,F12.3,'METERS')
      DATA DENT/6H IRISE/
C
C     INITIALIZE WAFER UP-DRIFT INTERPOLATION ARRAYS AND WAFER DATA
C     ARRAYS
C
      DO 2 KA=1,90
      DO 2 KB=1,2
    2 DPX(KB,KA)=0.0
      DO 3 KC=1,8
      DO 3 KQ=1,2
    3 DPST(KC,KQ)=0.0
      IF(KDI)5,5,4
    4 KDPST=KDI
      DPSTK=KDPST
```

```
      GO TO 6
    5 DPSTK=1.0+(CX(4,MCX)-CX(3,MCX))/100.0
      IF(DPSTK-3.0)51,52,52
   51 DPSTK=3.0
   52 KDPST=DPSTK
      DPSTK=KDPST
C
C     COMPUTE WAFER DP-DRIFT INTERPOLATION ARRAYS
C
    6 DO 7 KD=1,MCX
      IF(CX(7,KD)-CX(6,KD))53,53,54
   53 DPX(1,KD)=0.0
      GO TO 55
   54 DPX(1,KD)=(CX(7,KD)-CX(6,KD))/(CX(4,KD)-CX(3,KD))
   55 IF(CX(6,KD))56,56,57
   56 DPX(2,KD)=0.0
      GO TO 7
   57 DENOM=CX(3,KD)-ZBRSTZ
      IF(DENOM)58,56,58
   58 DPX(2,KD)=CX(6,KD)/DENOM
    7 CONTINUE
      GO TO (190,188),KRX
  188 WRITE(ISOUT,444)
  190 AREAMX=3.1415926*CX(5,MCX)**2
C
C     SET NOMINAL WAFER EDGE LENGTH IF WAFER RADII ARE TO BE SUBDIVIDED
C
      IF(IRAD)78,78,79
   78 BZ=0.
      GO TO 77
   79 BZ=CX(5,MCX)/FLOAT(IRAD)
   77 REWIND IRISE
      WRITE(IRISE)DENT
      WRITE(IRISE)FW,SSAM,SLDTMP,TMSD,SD,W,HEIGHT,BZ,RFD,IRAD,
     1CX(5,MCX),ZBRSTZ
      WRITE(IRISE)(DNID(I),I=1,12)
      WRITE(IRISE)(DETID(I),I=1,12)
      WRITE(IRISE)NDSTR
      WRITE(IRISE)(PS(J),FMASS(J),DIAM(J),J=1,NDSTR)
      WRITE(IRISE)KDPST
      WRITE(IRISE)NPVA
      WRITE(IRISE)(ALT(J),ETA(J),RHZ(J),J=1,NPVA)
      WRITE(IRISE)MCX
      WRITE(IRISE)(CX(3,J),CX(4,J),CX(1,J),CX(6,J),CX(7,J),J=1,MCX)
      WRITE(IRISE)NHODO
      IF(NHODO)7882,7882,7881
 7881 WRITE(IRISE)(ZV(J),VX(J),VY(J),J=1,NHODO)
 7882 FROG=1.3066667E-17*RFD
      BZ2=BZ/2.0
  120 LODD=0
C
C     COMPUTE IN-CLOUD AIR VISCOSITIES
C
      DO 6045 J=1,MCX
 6045 VISCX(J)=1.458E-6*CX(9,J)**1.5/(110.4+CX(9,J))
      KCX=MCX-1
C
```

```
C     ENTER OUTSIDE WAFER CALCULATION LOOP.  THIS LOOP DEFINES PARTICLE
C     SIZE CLASSES.
C
  200 DO 278 MA=1,NDSTR
      KDPS=2*KDPST
C
C
C     ENTER MIDDLE WAFER CALCULATION LOOP.  THIS LOOP DEFINES CLOUD
C     WAFER SUBDIVISIONS.
C
      DO 258 MB=1,KDPS
C
C     COMPUTE WAFER TOP OR BOTTOM INDICATOR, MBT
C         IF MB IS ODD, MBT=2        THIS SPECIFIES A WAFER BOTTOM
C         IF MB IS EVEN, MBT=1       THIS SPECIFIES A WAFER TOP
C
      MBT=2*((MB+1)/2)-MB+1
C
C     INITIAL DPST VARIABLES
C
      DPST(1,MBT)=CX(1,1)
      DPST(3,MBT)=CX(5,MCX)
      GO TO (202,201),MBT
  201 DPST(4,MBT)=DIAM(MA)
      GO TO 203
  202 DPST(4,MBT)=DIAM(MA+1)
  203 DPST(5 ,MBT)=SSAM*FMASS(MA)/DPSTK
      BM=MB/2
      DPST(2 ,MBT)=CX(3,1)+(CX(4,1)-CX(3,1))/KDI*BM
      ZLST=DPST(2,MBT)
      KBASE=1
      JBASE=1
C
C     ENTER INSIDE WAFER CALCULATION LOOP. THIS LOOP DEFINES CLOUD
C     RISE HISTORY TIMES IN THE CX ARRAY
C
C
C     COMPUTE DPST TRAVEL
C
      DO 238 MC=1,KCX
      ZVSB=DPST( 2,MBT)-CX(3,MC)
      IF(ZVSB)204,210,210
  204 GO TO (206,208),KBASE
C
C     ADJUST DPST RADIUS AND ALTITUDE FOR LEAVING CLOUD
C
  206 KBASE=2
      MD=MC-1
  207 EXTM=(ZLST-CX(3,MD))/(CX(6,MD)-UP+DN)
 1207 DPST(3,MBT)=CX(5,MD)+EXTM*CX(8,MD)
      DPST( 2,MBT)=ZLST+(UP-DN)*EXTM
C
C     IF THE WAFER IS ON THE GROUND, JUMP THE INNER LOOP.  IF NOT,
C     COMPUTE THE POSITION OF THE WAFER BELOW THE CLOUD BASE.
C
      GO TO (1208,233),JBASE
 1208 DPST( 2,MBT)=DPST( 2,MBT)+(CX(6,MD)-DN)*(CX(2,MD)-EXTM)
```

```
C
C     COMPUTE BELOW CLOUD AIR DENSITY AND VISCOSITY
C
  208 UP=CX(6,MC)+ZVSB*DPX(2,MC)
      CALL TRPL(DPST( 2,MBT),NPVA,ALT,RHZ,DEN)
      CALL TRPL(DPST( 2,MBT),NPVA,ALT,ETA,VIS)
      GO TO 212
C
C     COMPUTE INSIDE CLOUD GAS DENSITY AND VISCOSITY
C
  210 UP=CX(6,MC)+ZVSB*DPX(1,MC)
      FC=(DPST(1,MBT)-CX(1,MC))/(CX(1,MC+1)-CX(1,MC))
      DEN=CX(10,MC)+(CX(10,MC+1)-CX(10,MC))*FC
      VIS=VISCX(MC)+(VISCX(MC+1)-VISCX(MC))*FC
C
C     COMPUTE FALL SPEEDS
C
  212 VO=DPST(4,MBT)/VIS
      V1=DPST(4,MBT)*VO*FROG
      CDRR=V1*VO*DEN
      IF(CDRR-140.0)701,701,749
  749 IF(ISOUT.LT.0)GO TO 760
  750 IF(CDRR-4.5E+7)760,751,751
  751 WRITE(ISOUT,758)DPST(4,MBT),DPST( 2,MBT)
      GO TO 760
  701 DN=V1*(41666.7+CDRR*(-2.3363E+2+CDRR*(2.0154-6.9105E-3*CDRR)))
      GO TO 765
  760 QLOGA=ALOG10(CDRR)-20.773
      DN=50657.0*V1*CDRR**((QLOGA*QLOGA-443.98)*0.0011235)
  765 DN=DN*(1.0+0.233/(DPST(4,MBT)*DEN))
      ZNXT=DPST( 2,MBT)+CX(2,MC)*(UP-DN)
C
C     HAS THE PARTICLE REACHED THE GROUND-
C          YES TO 220
C         NO TO 230
C
      IF(ZNXT-ZBRSTZ)220,220,230
C
C     COMPUTE DPST TIME OF ARRIVAL ON FALLOUT FIELD
C
  220 EXTM=(ZBRSTZ-DPST( 2,MBT))/(UP-DN)
      DPST(1,MBT)=DPST(1,MBT)+EXTM
      DPST( 2,MBT)=ZBRSTZ
      JBASE=2
      MD=MC
      GO TO (1207,233),KBASE
  230 DPST(1,MBT)=DPST(1,MBT)+CX(2,MC)
      ZLST=DPST(2,MBT)
      DPST(2,MBT)=ZNXT
  238 CONTINUE
  233 GO TO (241,2440),MBT
C
C     IF BOTH TOP AND BOTTOM HAVE BEEN TREATED, ARE THE TOP AND BOTTOM
C     RADII THE SAME---
C        YES TO 5443
C        NO TO 2401
C
```

```
  241 IF(DPST(3,1)-DPST(3,2))2440,2440,2441
 2440 IFLAG=1
      GO TO (240,258),MBT
  240 GO TO(5442,235),KRX
  235 WRITE(ISOUT,777)(DPST(I,MBT),I=1,8),MBT,IFLAG
 2441 IFLAG=2
      GO TO (2401,2351),KRX
 2351 WRITE(ISOUT,777)(DPST(I,MBT),I=1,8),MBT,IFLAG
 2401 IF(DPST(2,1)-ZBRSTZ)259,259,2448
C
C     SPECIFY FINAL DPST ARRAY IF BOTH TOP AND BOTTOM OF WAFER ARE ON
C     THE GROUND
C
  259 IFLAG=1
      DPST(1,MBT)=0.5*(DPST(1,1)+DPST(1,2))
      DPST(2,MBT)=DPST(2,1)
      DPST(3,MBT)=0.5*(DPST(3,1)+DPST(3,2))
      DPST(4,MBT)=SQRT(DPST(4,1)*DPST(4,2))
      DPST(5,MBT)=DPST(5,1)
      DPST(6,MBT)=0.
      DPST(7,MBT)=0.
      DPST(8,MBT)=0.
      GO TO 5447
C
C     DETERMINE PARAMETERS TO BE USED TO SUBDIVIDE A WAFER WHOSE TOP
C     AND BOTTOM HAVE DIFFERENT RADII
C
 2448 AL=DPST(3,1)/DPST(3,2)
      RB=3.1415927*DPST(3,2)**2
      KDIP=AL
      IF(KDIP-10)2442,2442,2443
 2443 KDIP=10
      GO TO 2444
 2442 IF(KDIP-2)2450,2444,2444
 2450 IF(AL-1.5)2451,2452,2452
 2451 KDIP=1
      GO TO 2444
 2452 KDIP=2
 2444 ZD=DPST(2,1)-DPST(2,2)
      FK=FLOAT(KDIP)
      DZ=ZD/FK
      ALL=0.5*ZD/ALOG(AL)
C
C     SPECIFY PPST ARRAYS FOR THE WAFER SUBDIVISIONS
C
      DO 2445 I=1,KDIP
      FI=FLOAT(I)
      A=DPST(2,2)+(FI-1.)*DZ
      B=A+DZ
      A1=AL**(2.0*(B-DPST(2,2))/ZD)
      A2=AL**(2.0*(A-DPST(2,2))/ZD)
      PPST(2,I)=ALL*(ALOG(0.5*(A1+A2)))+DPST(2,2)
      PPST(3,I)=DPST(3,2)*(AL**((PPST(2,I)-DPST(2,2))/ZD))
      PPST(1,I)=DPST(1,MBT)
      PPST(4,I)=SQRT(DPST(4,1)*DPST(4,2))
      PPST(5,I)=DPST(5,MBT)/FK
      PPST(6,I)=DZ
```

```
      PPST(7,I)=A
      PPST(8,I)=RB*ALL*(A1-A2)
 2445 CONTINUE
 5443 IP=0
 5445 IP=IP+1
C
C     SET UP THE DPST ARRAY FOR A WAFER SUBDIVISION FROM THE PPST ARRAY
C
      DO 5444 J=1,J
 5444 DPST(J,MBT)=PPST(J,IP)
 5442 GO TO (5448,5447),IFLAG
C
C     SPECIFY FINAL DPST ARRAY FOR A WAFER WITH EQUAL BASE AND TOP RADII
C
 5448 DPST(6,MBT)= DPST(2,1)-DPST(2,2)
      DPST(2,MBT)=(DPST(2,1)+DPST(2,2))*0.5
      DPST(4,MBT)=SQRT(DPST(4,1)*DPST(4,2))
      DPST(7,MBT)=DPST(2,2)
      DPST(8,MBT)=DPST(6,MBT)*3.1415927*DPST(3,1)**2
      GO TO (5447,5826),KRX
 5826 WRITE(ISOUT,666)(DPST(I,MBT),I=1,8),MBT,IFLAG
 5447 IF(IRAD)5022,1022,783
C
C
C     INITIALIZE FOR HORIZONTAL WAFER SUBDIVISION
C
  783 XR=BZ2
      YR=BZ2
 5060 RADIUS=DPST(3,MBT)
      RAD2=RADIUS**2
 5010 IF(RAD2-2.0*BZ2**2)5022,1004,1004
C
C
C
C     SPECIFY GDPST ARRAY FOR WAFERS THAT ARE NOT TO BE SUBDIVIDED
C     HORIZONTALLY
C
 5022 LODD=LODD+1
      GDPST(6,LODD)=DPST(2,MBT)
      GDPST(4,LODD)=DPST(4,MBT)*1.0E-6
      GDPST(3,LODD)=DPST( 1,MBT)
      GDPST(5,LODD)=DPST(5,MBT)
      GDPST(1,LODD)=0.
      GDPST(2,LODD)=0.
      GDPST(7,LODD)=DPST(3,MBT)
      GDPST(8,LODD)=DPST(6,MBT)
      GDPST(9,LODD)=DPST(7,MBT)
      GDPST(10,LODD)=DPST(8,MBT)
      GO TO 5030
 1003 IF((XR)**2+(YR)**2-RAD2)1001,1001,1002
C
C     SUBDIVIDE WAFERS HORIZONTALLY AND SPECIFY THE GDPST ARRAY DATA
C
C
C      COUNT THE TOTAL NUMBER OF HORIZONTAL SUBDIVISIONS
C
 1004 EX=BZ2
```

```
      EY=BZ2                                                            RSXP 343
      CNT=4.0                                                           RSXP 344
 7210 EX=EX+BZ                                                          RSXP 345
      IF(EX**2+EY**2-RAD2)7201,7201,7202                                RSXP 346
 7201 CNT=CNT+4.0                                                       RSXP 347
      GO TO 7210                                                        RSXP 348
 7202 EX=BZ2                                                            RSXP 349
      EY=EY+BZ                                                          RSXP 350
      IF(EX**2+EY**2-RAD2)7201,7201,7203                                RSXP 351
 7203 CMA=DPST(5,MBT)/CNT                                               RSXP 352
 1001 LODD=LODD+1                                                       RSXP 353
      LL=LODD+3                                                         RSXP 354
      DO 1050 J=LODD,LL                                                 RSXP 355
      GDPST(9,J)=DPST(7,MBT)                                            RSXP 356
      GDPST(10,J)=DPST(8,MBT)/CNT                                       RSXP 357
      GDPST(7,J)=BZ2                                                    RSXP 358
      GDPST(8,J)=DPST(6,MBT)                                            RSXP 359
      GDPST(6,J)=DPST(2,MBT)                                            RSXP 360
      GDPST(4,J)=DPST(4,MBT)*1.0E-6                                     RSXP 361
      GDPST(3,J)=DPST(1,MBT)                                            RSXP 362
 1050 GDPST(5,J)=CMA                                                    RSXP 363
      GDPST(1,LODD)=XR                                                  RSXP 364
      GDPST(2,LODD)=YR                                                  RSXP 365
      LODD=LODD+1                                                       RSXP 366
      GDPST(1,LODD)=XR                                                  RSXP 367
      GDPST(2,LODD)=-YR                                                 RSXP 368
      LODD=LODD+1                                                       RSXP 369
      GDPST(1,LODD)=-XR                                                 RSXP 370
      GDPST(2,LODD)=-YR                                                 RSXP 371
      LODD=LODD+1                                                       RSXP 372
      GDPST(1,LODD)=-XR                                                 RSXP 373
      GDPST(2,LODD)=YR                                                  RSXP 374
 5030 IF(LODD- 97)1100,1010,1010                                        RSXP 375
 1100 IF(IRAD)2585,2585,1101                                            RSXP 376
 1101 XR=XR+BZ                                                          RSXP 377
      GO TO 1003                                                        RSXP 378
 1002 YR=YR+BZ                                                          RSXP 379
      XR=BZ2                                                            RSXP 380
      IF(YR-RADIUS)1003,1003,2585                                       RSXP 381
C                                                                       RSXP 382
C     LOAD THE GDPST ARRAYS ON THE CRM OUTPUT TAPE                      RSXP 383
C                                                                       RSXP 384
 1010 WRITE(IRISE)LODD                                                  RSXP 385
      WRITE(IRISE)(GDPST(1,J),GDPST(2,J),GDPST(3,J),GDPST(4,J),GDPST(5,JRSXP 386
     1),GDPST(6,J),GDPST(7,J),GDPST(8,J),GDPST(9,J),GDPST(10,J),J=1,LODDRSXP 387
     2)                                                                 RSXP 388
      LODD=0                                                            RSXP 389
      GO TO 1100                                                        RSXP 390
 2585 GO TO (258 ,2586),IFLAG                                           RSXP 391
 2586 IF(IP-KDIP)5445,258,258                                           RSXP 392
  258 CONTINUE                                                          RSXP 393
  278 CONTINUE                                                          RSXP 394
C                                                                       RSXP 395
C     LOAD FINAL RESIDUE OF GDPST DATA ON THE CRM OUTPUT TAPE           RSXP 396
C                                                                       RSXP 397
 1030 WRITE(IRISE)LODD                                                  RSXP 398
      WRITE(IRISE)(GDPST(1,J),GDPST(2,J),GDPST(3,J),GDPST(4,J),GDPST(5,JRSXP 399
```

```
1),GDPST(6,J),GDPST(7,J),GDPST(8,J),GDPST(9,J),GDPST(10,J),J=1,LODDRSXP 400
2)                                                                      RSXP 401
 LODD=0                                                                 RSXP 402
 WRITE(IRISE)LODD                                                       RSXP 403
 END FILE IRISE                                                         RSXP 404
 REWIND IRISE                                                           RSXP 405
 RETURN                                                                 RSXP 406
 END                                                                    RSXP 407
```

```
      SUBROUTINE TRPL (
     1  ARG, NPR, PARA, PARB, VRB)
C
C ***********************************************************************
C
C     TRPL USES LINEAR INTERPOLATION TO LOCATE POSITION OF ARG WITHIN
C     THE ONE-DIMENSIONAL ARRAY PARA AND COMPUTES FOR THE CORRESPONDING
C     POSITION IN THE ONE-DIMENSIONAL ARRAY PARB, VRB. NPR IS THE
C     DIMENSION OF PARA AND PARB (WHOSE ELEMENTS CORRESPOND ONE TO ONE).
C     IF ARG IS OUTSIDE THE TABULATED VALUES OF PARA, VRB IS SELECTED
C     FROM THE CORRESPONDING END OF PARB.
C     PARA IS ORDERED FROM LEAST (PARA (1)) TO GREATEST (PARA (NPR))
C
C ***********************************************************************
C
      DIMENSION
     1  PARA (1), PARB (1)
C
C ***********************************************************************
C ***********************************************************************
C
  020 IF (ARG - PARA (1)) 022, 022, 040
  022 MB = 1
  024 VRB = PARB (MB)
  026 RETURN
  040 DO 054 MA =2, NPR
      IF (ARG - PARA (MA)) 048, 044, 054
  044 MB = MA
      GO TO 024
  048 VRB = (ARG - PARA (MA - 1)) * (PARB (MA) - PARB (MA - 1)) /
     1  (PARA (MA) - PARA (MA - 1)) + PARB (MA - 1)
      GO TO 026
  054 CONTINUE
      MB = NPR
      GO TO 024
      END
```

SAMPLE PROBLEM AND PRINTOUT

On pp. 144 through 153 is presented a printout of a cloud rise calculation suitable for debugging usage. All quantities are labeled and have been discussed fully in the preceding sections. The atmosphere table printout is turned on but the debug printouts are off.

```
                         * * * * * * * * * * *
T H E   D E P A R T M E N T   O F   D E F E N S E   F A L L O U T   P R E D I C T I O N   S Y S T E M
                         * * * * * * * * * * *

                            CLOUD-RISE MODEL

                              PREPARED BY
                    NAVAL RADIOLOGICAL DEFENSE LABORATORY
                              S.F.,CALIF.
                                 AND
                           ARCON CORPORATION
                           WAKEFIELD, MASS.

CLOUD RISE RUN IDENTIFICATION -   BRAVO 15 MT      15 OCTOBER 1970          IBM 360/75

ATMOSPHERE IDENTIFICATION     -   BRAVO 15 MT      15 OCTOBER 1970          SET C ATMOSPHERE

ELEVATION OF GROUND ZERO =       0.0 METERS
SOIL SOLIDIFICATION TEMPERATURE =   2900.0 DEGREES KELVIN
PARTICLE DENSITY (C.G.S.) =   2.6000
YIELDS (KT) -
    TOTAL =  0.1500E 05    FISSION =  0.1500E 05
FRACTION OF AVAILABLE ENERGY USED TO HEAT AIR INITIALLY =  0.1000E 01
FRACTION OF AVAILABLE ENERGY USED TO HEAT LIQUID WATER INITIALLY =  0.0

COMPUTATION CONTROL INPUTS-
   NOISTE IHISTR     KOI    IRAD    KCLD     KRX    IRAM    KATM
     50      1        4      0       0       0       0       1

COMPUTATION CONTROLS -
    NUMBER OF PARTICLE SIZE CLASSES REQUESTED =   10
    NUMBER OF CLOUD SUBDIVISIONS(WAFERS) PER SIZE CLASS =    4
    WAFER SUBDIVISION FACTOR =    0
```

ATMOSPHERE

ALT	ATP	RHZ	ETA	PRS	GRV	SLM	RLH
-0.10000E 04	0.29466E 03	0.13470E 01	0.18206E-04	0.11392E 04	0.98097E 01	0.60323E-07	0.77000E 02
-0.80000E 03	0.29336E 03	0.13219E 01	0.18144E-04	0.11131E 04	0.98091E 01	0.61471E-07	0.77000E 02
-0.60000E 03	0.29206E 03	0.12972E 01	0.18082E-04	0.10874E 04	0.98085E 01	0.62645E-07	0.77000E 02
-0.40000E 03	0.29076E 03	0.12728E 01	0.18019E-04	0.10622E 04	0.98079E 01	0.63845E-07	0.77000E 02
-0.20000E 03	0.28946E 03	0.12487E 01	0.17957E-04	0.10375E 04	0.98073E 01	0.65073E-07	0.77000E 02
0.0	0.29567E 03	0.11697E 01	0.18444E-04	0.10061E 04	0.98000E 01	0.69471E-07	0.77000E 02
0.20000E 03	0.29791E 03	0.11521E 01	0.18356E-04	0.98507E 03	0.98000E 01	0.70514E-07	0.81265E 02
0.40000E 03	0.29595E 03	0.11346E 01	0.18267E-04	0.96404E 03	0.98000E 01	0.71602E-07	0.85530E 02
0.60000E 03	0.29409E 03	0.11171E 01	0.18179E-04	0.94301E 03	0.98000E 01	0.72739E-07	0.89795E 02
0.80000E 03	0.29256E 03	0.10970E 01	0.18106E-04	0.92139E 03	0.98000E 01	0.74058E-07	0.90000E 02
0.10000E 04	0.29105E 03	0.10767E 01	0.18033E-04	0.89973E 03	0.98000E 01	0.75449E-07	0.90000E 02
0.12000E 04	0.28954E 03	0.10565E 01	0.17961E-04	0.87806E 03	0.98000E 01	0.76509E-07	0.90000E 02
0.14000E 04	0.28863E 03	0.10254E 01	0.17917E-04	0.85791E 03	0.98000E 01	0.78469E-07	0.85255E 02
0.16000E 04	0.28778E 03	0.10142E 01	0.17876E-04	0.83790E 03	0.98000E 01	0.80107E-07	0.80005E 02
0.18000E 04	0.28692E 03	0.99365E 00	0.17835E-04	0.81788E 03	0.98000E 01	0.81822E-07	0.74755E 02
0.20000E 04	0.28677E 03	0.97099E 00	0.17827E-04	0.79927E 03	0.98000E 01	0.83684E-07	0.60239E 02
0.22000E 04	0.28676E 03	0.94878E 00	0.17326E-04	0.78059E 03	0.98000E 01	0.85643E-07	0.44153E 02
0.24000E 04	0.28671E 03	0.92657E 00	0.17324E-04	0.76253E 03	0.98000E 01	0.87697E-07	0.29037E 02
0.26000E 04	0.28546E 03	0.90661E 00	0.17765E-04	0.74465E 03	0.98000E 01	0.89413E-07	0.29241E 02
0.28000E 04	0.28397E 03	0.89166E 00	0.17591E-04	0.72697E 03	0.98000E 01	0.91108E-07	0.34491E 02
0.30000E 04	0.28246E 03	0.87472E 00	0.17518E-04	0.70925E 03	0.98000E 01	0.92898E-07	0.39740E 02
0.32000E 04	0.28110E 03	0.85753E 00	0.17552E-04	0.69203E 03	0.98000E 01	0.94741E-07	0.39753E 02
0.34000E 04	0.27979E 03	0.84027E 00	0.17437E-04	0.67497E 03	0.98000E 01	0.96693E-07	0.33113E 02
0.36000E 04	0.27848E 03	0.82300E 00	0.17423E-04	0.65791E 03	0.98000E 01	0.98725E-07	0.36473E 02
0.38000E 04	0.27754E 03	0.80582E 00	0.17377E-04	0.64202E 03	0.98000E 01	0.10093E-06	0.33431E 02
0.40000E 04	0.27675E 03	0.78867E 00	0.17338E-04	0.62660E 03	0.98000E 01	0.10301E-06	0.29822E 02
0.42000E 04	0.27596E 03	0.77153E 00	0.17300E-04	0.61118E 03	0.98000E 01	0.10531E-06	0.26213E 02
0.44000E 04	0.27470E 03	0.75600E 00	0.17237E-04	0.59620E 03	0.98000E 01	0.10747E-06	0.27832E 02
0.46000E 04	0.27319E 03	0.74129E 00	0.17162E-04	0.58143E 03	0.98000E 01	0.10959E-06	0.32097E 02
0.48000E 04	0.27168E 03	0.72658E 00	0.17083E-04	0.56667E 03	0.98000E 01	0.11182E-06	0.36362E 02
0.50000E 04	0.27055E 03	0.71216E 00	0.17032E-04	0.55312E 03	0.98000E 01	0.11409E-06	0.35181E 02
0.52000E 04	0.26967E 03	0.69793E 00	0.16988E-04	0.54032E 03	0.98000E 01	0.11641E-06	0.33229E 02
0.54000E 04	0.26878E 03	0.68371E 00	0.16944E-04	0.52753E 03	0.98000E 01	0.11894E-06	0.30275E 02
0.56000E 04	0.26764E 03	0.67043E 00	0.16886E-04	0.51511E 03	0.98000E 01	0.12119E-06	0.31050E 02
0.58000E 04	0.26629E 03	0.65788E 00	0.16319E-04	0.50297E 03	0.98000E 01	0.12348E-06	0.34659E 02
0.60000E 04	0.26435E 03	0.64532E 00	0.16752E-04	0.49083E 03	0.98000E 01	0.12590E-06	0.38257E 02
0.62000E 04	0.26361E 03	0.63271E 00	0.16684E-04	0.47393E 03	0.98000E 01	0.12838E-06	0.39659E 02
0.64000E 04	0.26229E 03	0.62003E 00	0.16617E-04	0.46725E 03	0.98000E 01	0.13093E-06	0.39033E 02
0.66000E 04	0.26096E 03	0.60736E 00	0.16550E-04	0.45557E 03	0.98000E 01	0.13360E-06	0.39346E 02
0.68000E 04	0.25963E 03	0.59469E 00	0.16483E-04	0.44385E 03	0.98000E 01	0.13642E-06	0.37690E 02
0.70000E 04	0.25831E 03	0.58201E 00	0.16415E-04	0.43221E 03	0.98000E 01	0.13939E-06	0.37034E 02
0.72000E 04	0.25698E 03	0.56934E 00	0.16348E-04	0.42053E 03	0.98000E 01	0.14253E-06	0.36378E 02
0.74000E 04	0.25566E 03	0.55666E 00	0.16281E-04	0.40885E 03	0.98000E 01	0.14585E-06	0.35722E 02
0.76000E 04	0.25433E 03	0.54399E 00	0.16214E-04	0.39717E 03	0.98000E 01	0.14936E-06	0.35066E 02
0.78000E 04	0.25256E 03	0.53372E 00	0.16128E-04	0.38731E 03	0.98000E 01	0.15212E-06	0.30500E 02
0.80000E 04	0.25096E 03	0.52373E 00	0.16039E-04	0.37765E 03	0.98000E 01	0.15433E-06	0.30000E 02
0.82000E 04	0.24925E 03	0.51373E 00	0.15951E-04	0.36822E 03	0.98000E 01	0.15788E-06	0.28500E 02
0.84000E 04	0.24755E 03	0.50373E 00	0.15862E-04	0.35864E 03	0.98000E 01	0.16099E-06	0.27500E 02
0.86000E 04	0.24584E 03	0.49373E 00	0.15774E-04	0.34906E 03	0.98000E 01	0.16427E-06	0.27000E 02
0.88000E 04	0.24413E 03	0.48373E 00	0.15686E-04	0.33948E 03	0.98000E 01	0.16773E-06	0.26000E 02
0.90000E 04	0.24243E 03	0.47373E 00	0.15597E-04	0.32990E 03	0.98000E 01	0.17140E-06	0.25000E 02
0.92000E 04	0.24074E 03	0.46394E 00	0.15510E-04	0.32065E 03	0.98000E 01	0.17509E-06	0.23500E 02
0.94000E 04	0.23912E 03	0.45467E 00	0.15423E-04	0.31242E 03	0.98000E 01	0.17852E-06	0.22500E 02
0.96000E 04	0.23749E 03	0.44540E 00	0.15337E-04	0.30415E 03	0.98000E 01	0.18212E-06	0.22000E 02
0.98000E 04	0.23586E 03	0.43613E 00	0.15251E-04	0.29588E 03	0.98000E 01	0.18593E-06	0.21000E 02
0.10000E 05	0.23424E 03	0.42686E 00	0.15164E-04	0.28762E 03	0.98000E 01	0.18995E-06	0.20000E 02
0.10200E 05	0.23261E 03	0.41759E 00	0.15078E-04	0.27935E 03	0.98000E 01	0.19421E-06	0.19750E 02
0.10400E 05	0.23098E 03	0.40831E 00	0.14992E-04	0.27108E 03	0.98000E 01	0.19874E-06	0.19500E 02

0.10600E 05	0.22933E 03	0.39904E 00	0.14905E-04	0.26281E 03	0.98000E 01	0.20354E-05	0.19250E 02
0.10800E 05	0.22772E 03	0.39062E 00	0.14817E-04	0.25550E 03	0.98000E 01	0.20788E-05	0.19000E 02
0.11000E 05	0.22608E 03	0.38263E 00	0.14728E-04	0.24867E 03	0.98000E 01	0.21205E-05	0.18750E 02
0.11200E 05	0.22444E 03	0.37466E 00	0.14639E-04	0.24185E 03	0.98000E 01	0.21645E-05	0.18500E 02
0.11400E 05	0.22280E 03	0.36665E 00	0.14550E-04	0.23502E 03	0.98000E 01	0.22111E-05	0.18250E 02
0.11600E 05	0.22116E 03	0.35866E 00	0.14461E-04	0.22820E 03	0.98000E 01	0.22604E-05	0.18000E 02
0.11800E 05	0.21952E 03	0.35067E 00	0.14372E-04	0.22138E 03	0.98000E 01	0.23128E-05	0.17750E 02
0.12000E 05	0.21787E 03	0.34269E 00	0.14282E-04	0.21455E 03	0.98000E 01	0.23685E-05	0.17500E 02
0.12200E 05	0.21624E 03	0.33474E 00	0.14194E-04	0.20778E 03	0.98000E 01	0.24274E-05	0.17250E 02
0.12400E 05	0.21479E 03	0.32776E 00	0.14113E-04	0.20227E 03	0.98000E 01	0.24768E-05	0.17000E 02
0.12600E 05	0.21333E 03	0.32078E 00	0.14032E-04	0.19676E 03	0.98000E 01	0.25288E-05	0.16750E 02
0.12800E 05	0.21187E 03	0.31380E 00	0.13951E-04	0.19124E 03	0.98000E 01	0.25840E-05	0.16500E 02
0.13000E 05	0.21042E 03	0.30682E 00	0.13870E-04	0.18573E 03	0.98000E 01	0.26424E-05	0.16250E 02
0.13200E 05	0.20896E 03	0.29984E 00	0.13789E-04	0.18022E 03	0.98000E 01	0.27043E-05	0.16000E 02
0.13400E 05	0.20750E 03	0.29286E 00	0.13708E-04	0.17471E 03	0.98000E 01	0.27701E-05	0.15750E 02
0.13600E 05	0.20605E 03	0.28588E 00	0.13627E-04	0.16920E 03	0.98000E 01	0.28406E-05	0.15500E 02
0.13800E 05	0.20471E 03	0.27921E 00	0.13552E-04	0.16413E 03	0.98000E 01	0.29091E-05	0.15000E 02
0.14000E 05	0.20354E 03	0.27297E 00	0.13485E-04	0.15966E 03	0.98000E 01	0.29734E-05	0.14900E 02
0.14200E 05	0.20237E 03	0.26673E 00	0.13419E-04	0.15520E 03	0.98000E 01	0.30413E-05	0.14400E 02
0.14400E 05	0.20121E 03	0.26048E 00	0.13353E-04	0.15074E 03	0.98000E 01	0.31133E-05	0.13900E 02
0.14600E 05	0.20004E 03	0.25424E 00	0.13287E-04	0.14628E 03	0.98000E 01	0.31896E-05	0.13200E 02
0.14800E 05	0.19887E 03	0.24800E 00	0.13220E-04	0.14182E 03	0.98000E 01	0.32706E-05	0.12600E 02
0.15000E 05	0.19770E 03	0.24176E 00	0.13154E-04	0.13735E 03	0.98000E 01	0.33572E-05	0.12000E 02
0.15200E 05	0.19653E 03	0.23552E 00	0.13088E-04	0.13289E 03	0.98000E 01	0.34434E-05	0.11400E 02
0.15400E 05	0.19591E 03	0.22942E 00	0.13052E-04	0.12906E 03	0.98000E 01	0.35405E-05	0.10800E 02
0.15600E 05	0.19543E 03	0.22337E 00	0.13024E-04	0.12535E 03	0.98000E 01	0.36352E-05	0.10200E 02
0.15800E 05	0.19494E 03	0.21731E 00	0.12996E-04	0.12171E 03	0.98000E 01	0.37357E-05	0.96000E 01
0.16000E 05	0.19445E 03	0.21126E 00	0.12968E-04	0.11804E 03	0.98000E 01	0.38422E-05	0.90000E 01
0.16200E 05	0.19397E 03	0.20520E 00	0.12940E-04	0.11437E 03	0.98000E 01	0.39560E-05	0.90000E 01
0.16400E 05	0.19348E 03	0.19914E 00	0.12913E-04	0.11069E 03	0.98000E 01	0.40769E-05	0.90000E 01
0.16600E 05	0.19300E 03	0.19309E 00	0.12885E-04	0.10701E 03	0.98000E 01	0.42066E-05	0.90000E 01
0.16800E 05	0.19525E 03	0.17350E 00	0.13014E-04	0.97275E 02	0.98000E 01	0.46817E-05	0.90000E 01
0.17000E 05	0.19481E 03	0.16757E 00	0.12983E-04	0.93704E 02	0.98000E 01	0.48490E-05	0.90000E 01
0.17200E 05	0.19550E 03	0.16170E 00	0.13034E-04	0.90725E 02	0.98000E 01	0.50273E-05	0.90000E 01
0.17400E 05	0.19640E 03	0.15584E 00	0.13080E-04	0.87774E 02	0.98000E 01	0.52189E-05	0.90000E 01
0.17600E 05	0.19719E 03	0.14997E 00	0.13125E-04	0.84805E 02	0.98000E 01	0.54231E-05	0.90000E 01
0.17800E 05	0.19798E 03	0.14411E 00	0.13171E-04	0.81845E 02	0.98000E 01	0.56420E-05	0.90000E 01
0.18000E 05	0.19878E 03	0.13824E 00	0.13216E-04	0.78866E 02	0.98000E 01	0.58777E-05	0.90000E 01
0.18200E 05	0.19957E 03	0.13349E 00	0.13261E-04	0.76425E 02	0.98000E 01	0.60903E-05	0.90000E 01
0.18400E 05	0.20037E 03	0.12874E 00	0.13306E-04	0.73979E 02	0.98000E 01	0.63172E-05	0.90000E 01
0.18600E 05	0.20116E 03	0.12399E 00	0.13351E-04	0.71528E 02	0.98000E 01	0.65594E-05	0.90000E 01
0.18800E 05	0.20195E 03	0.11923E 00	0.13396E-04	0.69078E 02	0.98000E 01	0.68188E-05	0.90000E 01
0.19000E 05	0.20275E 03	0.11448E 00	0.13441E-04	0.66627E 02	0.98000E 01	0.70976E-05	0.90000E 01
0.19200E 05	0.20354E 03	0.11067E 00	0.13486E-04	0.64596E 02	0.98000E 01	0.73495E-05	0.90000E 01
0.19400E 05	0.20433E 03	0.10675E 00	0.13531E-04	0.62561E 02	0.98000E 01	0.76178E-05	0.90000E 01
0.19600E 05	0.20513E 03	0.10289E 00	0.13575E-04	0.60528E 02	0.98000E 01	0.79045E-05	0.90000E 01
0.19800E 05	0.20592E 03	0.99020E-01	0.13620E-04	0.58495E 02	0.98000E 01	0.82107E-05	0.90000E 01
0.20000E 05	0.20671E 03	0.95154E-01	0.13665E-04	0.56462E 02	0.98000E 01	0.85390E-05	0.90000E 01
0.20200E 05	0.20751E 03	0.92005E-01	0.13709E-04	0.54771E 02	0.98000E 01	0.88367E-05	0.89500E 01
0.20400E 05	0.20830E 03	0.88845E-01	0.13753E-04	0.53080E 02	0.98000E 01	0.91529E-05	0.87000E 01
0.20600E 05	0.20909E 03	0.85691E-01	0.13797E-04	0.51389E 02	0.98000E 01	0.94900E-05	0.85500E 01
0.20800E 05	0.20989E 03	0.82536E-01	0.13842E-04	0.49691E 02	0.98000E 01	0.98504E-05	0.84000E 01
0.21000E 05	0.21064E 03	0.79382E-01	0.13886E-04	0.48007E 02	0.98000E 01	0.10236E-05	0.82500E 01
0.21200E 05	0.21147E 03	0.76795E-01	0.13930E-04	0.46594E 02	0.98000E 01	0.10596E-05	0.81000E 01
0.21400E 05	0.21226E 03	0.74209E-01	0.13974E-04	0.45181E 02	0.98000E 01	0.10958E-05	0.79500E 01
0.21600E 05	0.21305E 03	0.71622E-01	0.14018E-04	0.43768E 02	0.98000E 01	0.11354E-05	0.78000E 01
0.21800E 05	0.21385E 03	0.69135E-01	0.14062E-04	0.42354E 02	0.98000E 01	0.11776E-05	0.76500E 01
0.22000E 05	0.21464E 03	0.66648E-01	0.14106E-04	0.40941E 02	0.98000E 01	0.12228E-05	0.75000E 01
0.22200E 05	0.21512E 03	0.64356E-01	0.14132E-04	0.39754E 02	0.98000E 01	0.12621E-05	0.73500E 01
0.22400E 05	0.21560E 03	0.62343E-01	0.14159E-04	0.38567E 02	0.98000E 01	0.13039E-05	0.72000E 01
0.22600E 05	0.21609E 03	0.60290E-01	0.14185E-04	0.37380E 02	0.98000E 01	0.13483E-05	0.70500E 01
0.22800E 05	0.21657E 03	0.58238E-01	0.14212E-04	0.36193E 02	0.98000E 01	0.13956E-05	0.69000E 01
0.23000E 05	0.21705E 03	0.56185E-01	0.14238E-04	0.35006E 02	0.98000E 01	0.14462E-05	0.67500E 01

0.23200E 05	0.21748E 03	0.54474E-01	0.14262E-04	0.32955E 02	0.93000E 01	0.14519E-05	0.56000E 01
0.23400E 05	0.21772E 03	0.52763E-01	0.14286E-04	0.32553E 02	0.93000E 01	0.15406E-05	0.54500E 01
0.23600E 05	0.21796E 03	0.51052E-01	0.14310E-04	0.31980E 02	0.93000E 01	0.15923E-05	0.53000E 01
0.23800E 05	[illegible]	0.49341E-01	0.14333E-04	0.30981E 02	0.93000E 01	0.16472E-05	0.51500E 01
0.24000E 05	0.21923E 03	0.47630E-01	0.14358E-04	0.29973E 02	0.93000E 01	0.17060E-05	0.60000E 01
0.24200E 05	0.21966E 03	0.46156E-01	0.14381E-04	0.29120E 02	0.93000E 01	0.17594E-05	0.59000E 01
0.24400E 05	0.22010E 03	0.44758E-01	0.14405E-04	0.28267E 02	0.93000E 01	0.18161E-05	0.58000E 01
0.24600E 05	0.22054E 03	0.43322E-01	0.14429E-04	0.27414E 02	0.93000E 01	0.18764E-05	0.57000E 01
0.24800E 05	0.22097E 03	0.41866E-01	0.14453E-04	0.26561E 02	0.93000E 01	0.19404E-05	0.56000E 01
0.25000E 05	0.22141E 03	0.40443E-01	0.14476E-04	0.25708E 02	0.93000E 01	0.20096E-05	0.55000E 01
0.25200E 05	0.22184E 03	0.39242E-01	0.14500E-04	0.24963E 02	0.93000E 01	0.20711E-05	0.54000E 01
0.25400E 05	0.22228E 03	0.38035E-01	0.14524E-04	0.24259E 02	0.93000E 01	0.21371E-05	0.53000E 01
0.25600E 05	0.22271E 03	0.36927E-01	0.14547E-04	0.23585E 02	0.93000E 01	0.22071E-05	0.52000E 01
0.25800E 05	0.22315E 03	0.35620E-01	0.14571E-04	0.22810E 02	0.93000E 01	0.22818E-05	0.51000E 01
0.26000E 05	0.22359E 03	0.34412E-01	0.14595E-04	0.22066E 02	0.93000E 01	0.23611E-05	0.50000E 01
0.26200E 05	0.22402E 03	0.33203E-01	0.14619E-04	0.21465E 02	0.93000E 01	0.24338E-05	0.50000E 01
0.26400E 05	[illegible]	0.32374E-01	0.14642E-04	0.20551E 02	0.93000E 01	0.25107E-05	0.50000E 01
0.26600E 05	[illegible]	0.31255E-01	0.14665E-04	0.20234E 02	0.93000E 01	0.25923E-05	0.50000E 01
0.26800E 05	0.22533E 03	0.30336E-01	0.14689E-04	0.19617E 02	0.93000E 01	0.26791E-05	0.50000E 01
0.27000E 05	0.22576E 03	0.29317E-01	0.14712E-04	0.18999E 02	0.93000E 01	0.27715E-05	0.50000E 01
0.27200E 05	0.22620E 03	0.28453E-01	0.14736E-04	0.18473E 02	0.93000E 01	0.28560E-05	0.50000E 01
0.27400E 05	0.22663E 03	0.27593E-01	0.14759E-04	0.17954E 02	0.93000E 01	0.29451E-05	0.50000E 01
0.27600E 05	0.22707E 03	0.26739E-01	0.14783E-04	0.17422E 02	0.93000E 01	0.30399E-05	0.50000E 01
0.27800E 05	0.22750E 03	0.25870E-01	0.14806E-04	0.16696E 02	0.93000E 01	0.31405E-05	0.50000E 01
0.28000E 05	0.22794E 03	0.25019E-01	0.14830E-04	0.16370E 02	0.93000E 01	0.32477E-05	0.50000E 01
0.28200E 05	0.22837E 03	0.24292E-01	0.14853E-04	0.15921E 02	0.93000E 01	0.33456E-05	0.49000E 01
0.28400E 05	0.22881E 03	0.23565E-01	0.14876E-04	0.15472E 02	0.93000E 01	0.34493E-05	0.48000E 01
0.28600E 05	0.22924E 03	0.22838E-01	0.14900E-04	0.15023E 02	0.93000E 01	0.35531E-05	0.47000E 01
0.28800E 05	0.22968E 03	0.22111E-01	0.14923E-04	0.14574E 02	0.93000E 01	0.36757E-05	0.46000E 01
0.29000E 05	0.23011E 03	0.21383E-01	0.14946E-04	0.14125E 02	0.93000E 01	0.37997E-05	0.45000E 01
0.29200E 05	0.23055E 03	0.20768E-01	0.14970E-04	0.13741E 02	0.93000E 01	0.39133E-05	0.44000E 01
0.29400E 05	[illegible]	0.20152E-01	0.14993E-04	0.13357E 02	0.93000E 01	0.40334E-05	0.43000E 01
0.29600E 05	[illegible]	0.19537E-01	0.15016E-04	0.12974E 02	0.93000E 01	0.41603E-05	0.42000E 01
0.29800E 05	[illegible]	0.18921E-01	0.15039E-04	0.12590E 02	0.93000E 01	0.42952E-05	0.41000E 01
0.30000E 05	[illegible]	0.18306E-01	0.15062E-04	0.12206E 02	0.93000E 01	0.44387E-05	0.40000E 01
0.30200E 05	[illegible]	0.17784E-01	0.15086E-04	0.11877E 02	0.93000E 01	0.45701E-05	0.40000E 01
0.30400E 05	[illegible]	0.17261E-01	0.15109E-04	0.11549E 02	0.93000E 01	0.47098E-05	0.40000E 01
0.30600E 05	[illegible]	0.16739E-01	0.15132E-04	0.11220E 02	0.93000E 01	0.48558E-05	0.40000E 01
0.30800E 05	[illegible]	0.16216E-01	0.15155E-04	0.10891E 02	0.93000E 01	0.50117E-05	0.40000E 01
0.31000E 05	[illegible]	0.15694E-01	0.15179E-04	0.10562E 02	0.93000E 01	0.51775E-05	0.40000E 01
0.31200E 05	[illegible]	0.15250E-01	0.15201E-04	0.10280E 02	0.93000E 01	0.53293E-05	0.40000E 01
0.31400E 05	[illegible]	0.14806E-01	0.15224E-04	0.99983E 01	0.93000E 01	0.54897E-05	0.40000E 01
0.31600E 05	[illegible]	0.14362E-01	0.15247E-04	0.97163E 01	0.93000E 01	0.56594E-05	0.40000E 01
0.31800E 05	[illegible]	0.13918E-01	0.15270E-04	0.94343E 01	0.93000E 01	0.58334E-05	0.40000E 01
0.32000E 05	0.23663E 03	0.13474E-01	0.15293E-04	0.91523E 01	0.93000E 01	0.60303E-05	0.40000E 01
0.32200E 05	0.23707E 03	0.13096E-01	0.15316E-04	0.88510E 01	0.93000E 01	0.62059E-05	0.40000E 01
0.32400E 05	0.23750E 03	0.12718E-01	0.15339E-04	0.86677E 01	0.93000E 01	0.63909E-05	0.40000E 01
0.32600E 05	0.23794E 03	0.12340E-01	0.15362E-04	0.84254E 01	0.93000E 01	0.65869E-05	0.40000E 01
0.32800E 05	0.23837E 03	0.11962E-01	0.15385E-04	0.81821E 01	0.93000E 01	0.67941E-05	0.40000E 01
0.33000E 05	0.23881E 03	0.11584E-01	0.15408E-04	0.79400E 01	0.93000E 01	0.70144E-05	0.40000E 01
0.33200E 05	0.23924E 03	0.11262E-01	0.15431E-04	0.77325E 01	0.93000E 01	0.72163E-05	0.40000E 01
0.33400E 05	0.23968E 03	0.10940E-01	0.15454E-04	0.75243E 01	0.93000E 01	0.74296E-05	0.40000E 01
0.33600E 05	0.24011E 03	0.10618E-01	0.15476E-04	0.73160E 01	0.93000E 01	0.76549E-05	0.40000E 01
0.33800E 05	0.24054E 03	0.10296E-01	0.15499E-04	0.71078E 01	0.93000E 01	0.78932E-05	0.40000E 01
0.34000E 05	0.24098E 03	0.99742E-02	0.15522E-04	0.68995E 01	0.93000E 01	0.81464E-05	0.40000E 01
0.34200E 05	0.24141E 03	0.96994E-02	0.15545E-04	0.67201E 01	0.93000E 01	0.83788E-05	0.40000E 01
0.34400E 05	0.24185E 03	0.94245E-02	0.15567E-04	0.65407E 01	0.93000E 01	0.86243E-05	0.40000E 01
0.34600E 05	0.24228E 03	0.91496E-02	0.15590E-04	0.63612E 01	0.93000E 01	0.88834E-05	0.40000E 01
0.34800E 05	0.24271E 03	0.88747E-02	0.15613E-04	0.61818E 01	0.93000E 01	0.91574E-05	0.40000E 01
0.35000E 05	0.24315E 03	0.85998E-02	0.15636E-04	0.60024E 01	0.93000E 01	0.94482E-05	0.40000E 01
0.35200E 05	0.24358E 03	0.83649E-02	0.15658E-04	0.58477E 01	0.93000E 01	0.97153E-05	0.40000E 01
0.35400E 05	0.24402E 03	0.81301E-02	0.15681E-04	0.56930E 01	0.98000E 01	0.99974E-05	0.40000E 01
0.35600E 05	0.24445E 03	0.78953E-02	0.15704E-04	0.55384E 01	0.99000E 01	0.10295E-04	0.40000E 01

0.35800E 05	0.24489E 03	0.76644E-02	0.15726E-04	0.53637 01	0.93000E 01	0.10609E-04	0.40000E 01
0.36000E 05	0.24532E 03	0.74256E-02	0.15749E-04	0.52291E 01	0.93000E 01	0.10542E-04	0.40000E 01
0.36200E 05	0.24575E 03	0.72243E-02	0.15771E-04	0.50953E 01	0.93000E 01	0.11249E-04	0.40000E 01
0.36400E 05	0.24619E 03	0.70230E-02	0.15794E-04	0.49616E 01	0.93000E 01	0.11573E-04	0.40000E 01
0.36600E 05	0.24662E 03	0.68217E-02	0.15815E-04	0.48278E 01	0.93000E 01	0.11915E-04	0.40000E 01
0.36800E 05	0.24706E 03	0.66204E-02	0.15839E-04	0.46940E 01	0.93000E 01	0.12276E-04	0.40000E 01
0.37000E 05	0.24749E 03	0.64191E-02	0.15862E-04	[illegible]	0.93000E 01	0.12656E-04	0.40000E 01
0.37200E 05	0.24792E 03	0.62166E-02	0.15884E-04	0.44447E 01	0.93000E 01	0.13010E-04	0.40000E 01
0.37400E 05	0.24836E 03	0.60742E-02	0.15905E-04	0.43251E 01	0.93000E 01	0.13381E-04	0.40000E 01
0.37600E 05	0.24879E 03	0.59116E-02	0.15929E-04	0.42133E 01	0.93000E 01	0.13772E-04	0.40000E 01
0.37800E 05	0.24923E 03	0.57293E-02	0.15951E-04	0.41675E 01	0.93000E 01	0.14195E-04	0.40000E 01
0.38000E 05	0.24966E 03	0.55569E-02	0.15974E-04	0.39824E 01	0.93000E 01	0.14622E-04	0.40000E 01
0.38200E 05	0.25009E 03	0.54069E-02	0.15996E-04	0.38823E 01	0.93000E 01	0.15025E-04	0.40000E 01
0.38400E 05	0.25053E 03	0.52610E-02	0.16019E-04	0.37722E 01	0.93000E 01	0.15449E-04	0.40000E 01
0.38600E 05	0.25096E 03	0.51131E-02	0.16041E-04	0.36623E 01	0.93000E 01	0.15896E-04	0.40000E 01
0.38800E 05	0.25139E 03	0.49651E-02	0.16063E-04	0.35522E 01	0.93000E 01	[illegible]	0.40000E 01
0.39000E 05	0.25183E 03	0.48172E-02	0.16085E-04	0.34422E 01	0.93000E 01	[illegible]	0.40000E 01
0.39200E 05	0.25226E 03	0.46690E-02	0.16108E-04	[illegible]	0.93000E 01	0.17326E-04	0.40000E 01
0.39400E 05	0.25269E 03	[illegible]	0.16130E-04	[illegible]	0.93000E 01	[illegible]	0.40000E 01
[illegible]	0.25313E 03	[illegible]	0.16152E-04	0.32219E 01	0.93000E 01	0.18225E-04	0.40000E 01
[illegible]	[illegible]	[illegible]	0.16174E-04	[illegible]	0.93000E 01	0.18663E-04	[illegible]
[illegible]	[illegible]	[illegible]	0.16196E-04	[illegible]	0.93000E 01	[illegible]	[illegible]
0.40200E 05	[illegible]	[illegible]	0.16219E-04	0.29731E 01	0.93000E 01	0.19561E-04	0.40000E 01
[illegible]	[illegible]	[illegible]	0.16241E-04	[illegible]	0.93000E 01	0.20515E-04	0.40000E 01
0.40600E 05	[illegible]	[illegible]	0.16263E-04	[illegible]	0.93000E 01	[illegible]	0.40000E 01
[illegible]	[illegible]	[illegible]	0.16285E-04	[illegible]	0.93000E 01	0.21716E-04	0.40000E 01
0.41000E 05	[illegible]	[illegible]	0.16307E-04	[illegible]	0.93000E 01	[illegible]	0.40000E 01
0.41200E 05	0.25659E 03	[illegible]	0.16329E-04	[illegible]	0.93000E 01	[illegible]	0.40000E 01
0.41400E 05	0.25703E 03	[illegible]	0.16351E-04	[illegible]	0.93000E 01	[illegible]	0.40000E 01
0.41600E 05	0.25746E 03	[illegible]	0.16373E-04	[illegible]	0.93000E 01	0.24253E-04	0.40000E 01
0.41800E 05	0.25789E 03	[illegible]	0.16395E-04	[illegible]	0.93000E 01	0.24964E-04	0.40000E 01
0.42000E 05	0.25833E 03	[illegible]	0.16413E-04	[illegible]	0.93000E 01	0.25705E-04	0.40000E 01
0.42200E 05	0.25876E 03	[illegible]	0.16439E-04	0.22870E 01	0.93000E 01	0.26390E-04	0.40000E 01
[illegible]	0.25919E 03	[illegible]	0.16461E-04	[illegible]	0.93000E 01	0.27109E-04	0.40000E 01
0.42600E 05	0.25963E 03	0.29165E-02	0.16483E-04	0.21729E 01	0.93000E 01	0.27869E-04	0.40000E 01
0.42800E 05	[illegible]	0.28349E-02	0.16505E-04	0.21155E 01	0.93000E 01	0.28667E-04	0.40000E 01
0.43000E 05	0.26049E 03	0.27534E-02	0.16527E-04	0.20555E 01	0.93000E 01	0.29509E-04	0.40000E 01
0.43200E 05	[illegible]	[illegible]	0.16549E-04	0.20092E 01	0.93000E 01	0.30290E-04	0.40000E 01
0.43400E 05	0.26136E 03	0.26125E-02	0.16571E-04	0.19559E 01	0.93000E 01	0.31110E-04	0.40000E 01
0.43600E 05	0.26179E 03	0.25422E-02	0.16593E-04	0.19055E 01	0.93000E 01	0.31970E-04	0.40000E 01
0.43800E 05	[illegible]	0.24718E-02	0.16615E-04	0.18662E 01	0.93000E 01	0.32879E-04	0.40000E 01
0.44000E 05	[illegible]	[illegible]	0.16637E-04	0.18110E 01	0.93000E 01	0.33935E-04	0.40000E 01
0.44200E 05	[illegible]	[illegible]	0.16659E-04	0.17672E 01	0.93000E 01	0.34723E-04	0.40000E 01
0.44400E 05	[illegible]	0.22795E-02	0.16680E-04	0.17239E 01	0.93000E 01	0.35654E-04	0.40000E 01
0.44600E 05	[illegible]	0.22186E-02	0.16702E-04	0.16806E 01	0.93000E 01	0.36633E-04	0.40000E 01
0.44800E 05	[illegible]	0.21576E-02	0.16724E-04	0.16372E 01	0.93000E 01	0.37666E-04	0.40000E 01
0.45000E 05	0.26482E 03	0.20967E-02	0.16746E-04	0.15939E 01	0.93000E 01	0.33752E-04	0.40000E 01
0.45200E 05	0.26526E 03	0.20440E-02	0.16767E-04	0.15561E 01	0.93000E 01	0.33759E-04	0.40000E 01
0.45400E 05	0.26569E 03	0.19512E-02	0.16734E-04	0.15186E 01	0.93000E 01	0.40818E-04	0.40000E 01
0.45600E 05	0.26612E 03	0.19365E-02	0.16811E-04	0.14864E 01	0.93000E 01	0.41928E-04	0.40000E 01
0.45800E 05	0.26655E 03	0.18557E-02	0.16832E-04	0.14426E 01	0.93000E 01	0.43096E-04	0.40000E 01
0.46000E 05	0.26699E 03	[illegible]	0.16854E-04	0.14064E 01	0.93000E 01	0.44328E-04	0.40000E 01
0.46200E 05	0.26742E 03	0.17372E-02	0.16876E-04	0.13737E 01	0.93000E 01	0.45471E-04	0.40000E 01
0.46400E 05	0.26785E 03	0.17415E-02	0.16897E-04	0.13386E 01	0.93000E 01	0.45670E-04	0.40000E 01
0.46600E 05	0.26828E 03	0.16557E-02	0.16919E-04	0.13055E 01	0.93000E 01	0.47531E-04	0.40000E 01
0.46800E 05	0.26872E 03	0.16455E-02	0.16940E-04	0.12725E 01	0.93000E 01	0.49254E-04	0.40000E 01
0.47000E 05	0.26915E 03	0.16042E-02	0.16962E-04	0.12354E 01	0.93000E 01	0.50651E-04	0.40000E 01
0.47200E 05	0.26935E 03	0.15656E-02	0.16972E-04	0.12106E 01	0.93000E 01	0.51903E-04	0.40000E 01
0.47400E 05	0.26955E 03	0.15270E-02	0.16982E-04	0.11814E 01	0.93000E 01	0.53216E-04	0.40000E 01
0.47600E 05	0.26975E 03	0.14884E-02	0.16992E-04	0.11524E 01	0.93000E 01	0.54596E-04	0.40000E 01
0.47800E 05	0.26995E 03	0.14498E-02	0.17002E-04	0.11234E 01	0.93000E 01	0.56047E-04	0.40000E 01
0.48000E 05	0.27015E 03	0.14112E-02	0.17012E-04	0.10544E 01	0.93000E 01	0.57574E-04	0.40000E 01
0.48200E 05	0.27015E 03	0.13782E-02	0.17012E-04	0.10664E 01	0.93000E 01	0.58953E-04	0.40000E 01

0.48400E 05	0.27015E 03	0.13453E-02	0.17012E-04	0.10432E 01	0.93000E 01	0.60400E-04	0.40000E 01
0.48600E 05	0.27015E 03	0.13123E-02	0.17012E-04	0.10176E 01	0.93000E 01	0.61920E-04	0.40000E 01
0.48800E 05	0.27015E 03	0.12793E-02	0.17012E-04	0.99204E 00	0.93000E 01	0.63515E-04	0.40000E 01
0.49000E 05	0.27015E 03	0.12463E-02	0.17012E-04	0.96645E 00	0.93000E 01	0.65197E-04	0.40000E 01
0.49200E 05	0.27015E 03	0.12172E-02	0.17012E-04	0.94388E 00	0.93000E 01	0.66756E-04	0.40000E 01
0.49400E 05	0.27015E 03	0.11881E-02	0.17012E-04	0.92121E 00	0.93000E 01	0.68391E-04	0.40000E 01
0.49600E 05	0.27015E 03	0.11589E-02	0.17012E-04	0.89873E 00	0.93000E 01	0.70109E-04	0.40000E 01
0.49800E 05	0.27015E 03	0.11298E-02	0.17012E-04	0.87616E 00	0.93000E 01	0.71915E-04	0.40000E 01
0.50000E 05	0.27015E 03	0.11007E-02	0.17012E-04	0.85359E 00	0.93000E 01	0.73817E-04	0.40000E 01

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CLOUD RISE IS TERMINATED IN CXPN AT STATEMENT  243 BY THE   K RA SWITCH
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CLOUD RISE AND EXPANSION HISTORY TABLE CX

PARAMETERS FOR THE LOGNORMAL PARTICLE DIAMETER-MASS FREQUENCY DISTRIBUTION
GEOMETRIC MEAN = 0.13450E 03 MICROMETERS GEOMETRIC STANDARD DEVIATION = 0.21600E 01

CLOUD HISTORY TABLE

	CLOUD TIME (SEC)	CLOUD INTERVAL (SEC)	CLOUD BASE (M)	CLOUD TOP (M)	CLOUD RADIUS (M)	BASE RATE (M/SEC)	TOP RATE (M/SEC)	RADIAL RATE (M/SEC)	TEMPERATURE (K)	GAS DENSITY (KG/M**3)
1)	1.2878E 01	1.3750E-01	1.1630E 03	5.0251E 03	2.9157E 03	1.2210E 02	2.3753E 02	8.5844E 01	3.3830E 03	7.2018E-02
2)	1.3065E 01	4.3750E-01	1.1909E 03	5.0697E 03	2.9325E 03	1.2723E 02	2.4759E 02	9.3684E 01	3.3499E 03	7.2428E-02
3)	1.3503E 01	3.7500E-01	1.2465E 03	5.1780E 03	2.9735E 03	1.3794E 02	2.5345E 02	1.0165E 02	3.2702E 03	7.3444E-02
4)	1.4378E 01	1.5000E 00	1.3572E 03	5.4123E 03	3.0625E 03	1.5665E 02	3.1485E 02	1.1522E 02	[illegible]	7.5789E-02
5)	1.5878E 01	1.5000E 00	1.6022E 03	5.9702E 03	3.2353E 03	1.7590E 02	3.4231E 02	1.2705E 02	[illegible]	8.1605E-02
6)	1.7378E 01	2.5000E 00	1.8660E 03	[illegible]	3.4259E 03	1.7505E 02	3.4057E 02	1.0674E 02	[illegible]	1.0101E-01
7)	1.9878E 01	3.0000E 00	2.3037E 03	[illegible]	3.8423E 03	1.6000E 02	3.1311E 02	1.5278E 02	[illegible]	1.5743E-01
8)	2.2875E 01	3.5000E 00	2.7664E 03	[illegible]	4.3011E 03	1.4755E 02	2.9720E 02	1.2761E 02	[illegible]	2.1477E-01
9)	2.6378E 01	4.5000E 00	[illegible]	[illegible]	4.7473E 03	1.3067E 02	2.6554E 02	1.1845E 02	[illegible]	2.5251E-01
10)	3.0878E 01	5.5000E 00	3.9152E 03	[illegible]	[illegible]	[illegible]	2.5133E 02	1.0941E 02	[illegible]	2.9619E-01
11)	3.6378E 01	6.5000E 00	4.6310E 03	1.1764E 04	5.8625E 03	1.2530E 02	2.4364E 02	1.0115E 02	4.1410E 02	3.0965E-01
12)	4.2878E 01	8.0000E 00	5.4454E 03	1.3349E 04	6.5400E 03	1.2417E 02	2.4164E 02	9.7470E 01	3.5303E 02	3.0397E-01
13)	5.0878E 01	8.5000E 00	6.4338E 03	1.5282E 04	7.3197E 03	1.2527E 02	2.4378E 02	9.2727E 01	3.1391E 02	2.9114E-01
14)	5.9378E 01	1.0000E 01	7.5036E 03	1.7355E 04	8.1079E 03	1.2868E 02	2.5042E 02	9.7431E 01	2.8353E 02	2.5012E-01
15)	6.9378E 01	1.1500E 01	8.7503E 03	1.9859E 04	9.9622E 03	1.3369E 02	2.6019E 02	8.8649E 01	2.4957E 02	2.1272E-01
16)	8.0878E 01	1.3000E 01	1.0326E 04	2.2851E 04	1.0002E 04	1.3577E 02	2.5422E 02	1.3484E 02	2.2109E 02	1.6892E-01
17)	9.3878E 01	1.4500E 01	1.2053E 04	2.6296E 04	1.1755E 04	1.2252E 02	2.3343E 02	1.0251E 02	1.9573E 02	1.1518E-01
18)	1.0938E 02	1.9500E 01	1.3469E 04	2.9743E 04	1.3241E 04	8.7479E 01	1.7024E 02	9.0387E 01	1.7490E 02	9.4293E-02
19)	1.2788E 02	1.5000E 01	1.5575E 04	3.3063E 04	1.5304E 04	3.8979E 01	7.5955E 01	1.0620E 02	1.5959E 02	6.2471E-02
20)	1.4288E 02	2.0000E 01	1.6166E 04	3.4200E 04	1.6597E 04	7.8641E 00	4.4523E 00	1.2041E 02	1.6316E 02	5.4509E-02
21)	1.6288E 02	2.5000E 01	1.6217E 04	3.4289E 04	1.9005E 04	0.0	0.0	1.1965E 02	1.7152E 02	5.0534E-02
22)	1.8788E 02	2.0000E 01	1.6217E 04	3.4289E 04	2.1996E 04	0.0	0.0	1.1759E 02	1.8238E 02	4.7525E-02
23)	2.0788E 02	2.5000E 01	1.6217E 04	3.4289E 04	2.4348E 04	0.0	0.0	1.1540E 02	1.8875E 02	4.5920E-02
24)	2.3288E 02	3.0000E 01	1.6217E 04	3.4289E 04	2.7233E 04	0.0	0.0	1.1277E 02	1.9471E 02	4.4514E-02
25)	2.6288E 02	3.0000E 01	1.6217E 04	3.4289E 04	3.0616E 04	0.0	0.0	1.1004E 02	1.9983E 02	4.3372E-02
26)	2.9288E 02	3.0000E 01	1.6217E 04	3.4289E 04	3.3917E 04	0.0	0.0	1.0750E 02	2.0346E 02	4.2596E-02
27)	3.2288E 02	3.5000E 01	1.6217E 04	3.4289E 04	3.7142E 04	0.0	0.0	1.0438E 02	2.0610E 02	4.2048E-02
28)	3.5788E 02	3.5000E 01	1.6217E 04	3.4289E 04	4.0815E 04	0.0	0.0	1.0251E 02	2.0835E 02	4.1591E-02
29)	3.9288E 02	4.0000E 01	1.6217E 04	3.4289E 04	4.4404E 04	0.0	0.0	1.0013E 02	2.1300E 02	4.1262E-02
30)	4.3288E 02	4.5000E 01	1.6217E 04	3.4289E 04	4.8409E 04	0.0	0.0	9.7708E 01	2.1140E 02	4.0986E-02
31)	4.7789E 02	4.5000E 01	1.6217E 04	3.4289E 04	5.2805E 04	0.0	0.0	9.5420E 01	2.1256E 02	4.0760E-02
32)	5.2288E 02	4.5000E 01	1.6217E 04	3.4289E 04	5.7133E 04	0.0	0.0	9.3371E 01	2.1343E 02	4.0593E-02
33)	5.6788E 02	5.0000E 01	1.6217E 04	3.4289E 04	6.1332E 04	0.0	0.0	9.1427E 01	2.1409E 02	4.0465E-02
34)	6.1788E 02	5.5000E 01	1.6217E 04	3.4289E 04	6.5873E 04	0.0	0.0	8.9498E 01	2.1467E 02	4.0355E-02
35)	6.7289E 02	5.5000E 01	1.6217E 04	3.4289E 04	7.0795E 04	0.0	0.0	8.7681E 01	2.1516E 02	4.0242E-02
36)	7.2788E 02	6.0000E 01	1.6217E 04	3.4289E 04	7.5618E 04	0.0	0.0	8.5968E 01	2.1554E 02	4.0188E-02
37)	7.8788E 02	6.5000E 01	1.6217E 04	3.4289E 04	8.0776E 04	0.0	0.0	8.4290E 01	2.1588E 02	4.0125E-02
38)	8.5288E 02	6.5000E 01	1.6217E 04	3.4289E 04	8.6255E 04	0.0	0.0	8.2712E 01	2.1617E 02	4.0070E-02
39)	9.1788E 02	0.0	1.6217E 04	3.4289E 04	9.1631E 04	0.0	0.0	0.0	2.1640E 02	4.0026E-02

TIME OF SOIL SOLIDIFICATION = 15.6880 SEC

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APPENDIX A.2

SOME CLOUD RISE SIMULATION RESULTS

To assess the quality of the cloud rise simulation results and to determine yield dependence of critical model parameters, we have performed cloud rise simulations for 56 shots for which adequate observed data are available. For this work we obtained observed atmosphere data (pressure, temperature, and relative humidity as a function of altitude) for a large number of surface and air burst nuclear detonations.* These data were used along with known explosion energy yields and heights of burst. The simulated stabilized cloud top, base, and center altitudes then were compared with observed data taken from Volume V of DASA-1251[A.2.1]. The results are shown in Figures A.2.1, A.2.2, and A.2.3. Results are tabulated in Table A.2.1. The figures and the table show data for 54 shots; data for two shots are classified and are omitted. Comparison of observed with calculated data for these shots was used to determine values for the model parameters F, k_2, and k_3 (see pp. 17, 18). Considerable sensitivity was found to parameters F and k_2 (and to atmospheric stability as well).

With regard to accuracy of experimental data, we can expect that the pressure-temperature-altitude data are adequate. The stabilized cloud altitude data, however, are virtually always suspect. Indeed, we have no way to determine the possible range of error for individual data. Particularly suspect are stabilized cloud base altitude data, since we know, from personal observations of cinefilms of the late clouds from many shots, that a cap case altitude is usually difficult to define with precision. We did not include comparisons of stabilized cloud radii because there are relatively few reliable observations of cloud radii and, in any case, a stabilized cloud radius is virtually impossible to define since nuclear clouds never really cease their horizontal expansion.

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*Mr. Robert Tompkins of the Nuclear Effects Laboratory and Mr. Philip Allen and Mr. Jack Pales of the ESSA Research Station, Las Vegas, Nevada went to great trouble to gather data and information for us. This work would not have been possible without their help.

On the whole, the comparisons are satisfactory, though there does seem to be a trend to underestimate cloud top height through most of the midyield range. There are many cases of excellent agreement. It is perhaps significant that this is particularly true for the cloud top data for which we should have the most accurate observations.

In Figure A.2.4 we have the complete simulation history in terms of cloud top height, base height, and radius, for a 15 MT surface shot in a tropical atmosphere. The simulated data are reproduced in the Sample Problem and Printout section above. These results can be compared with observed data for shot CASTLE Bravo[A.2.2]. The agreement is quite gratifying.

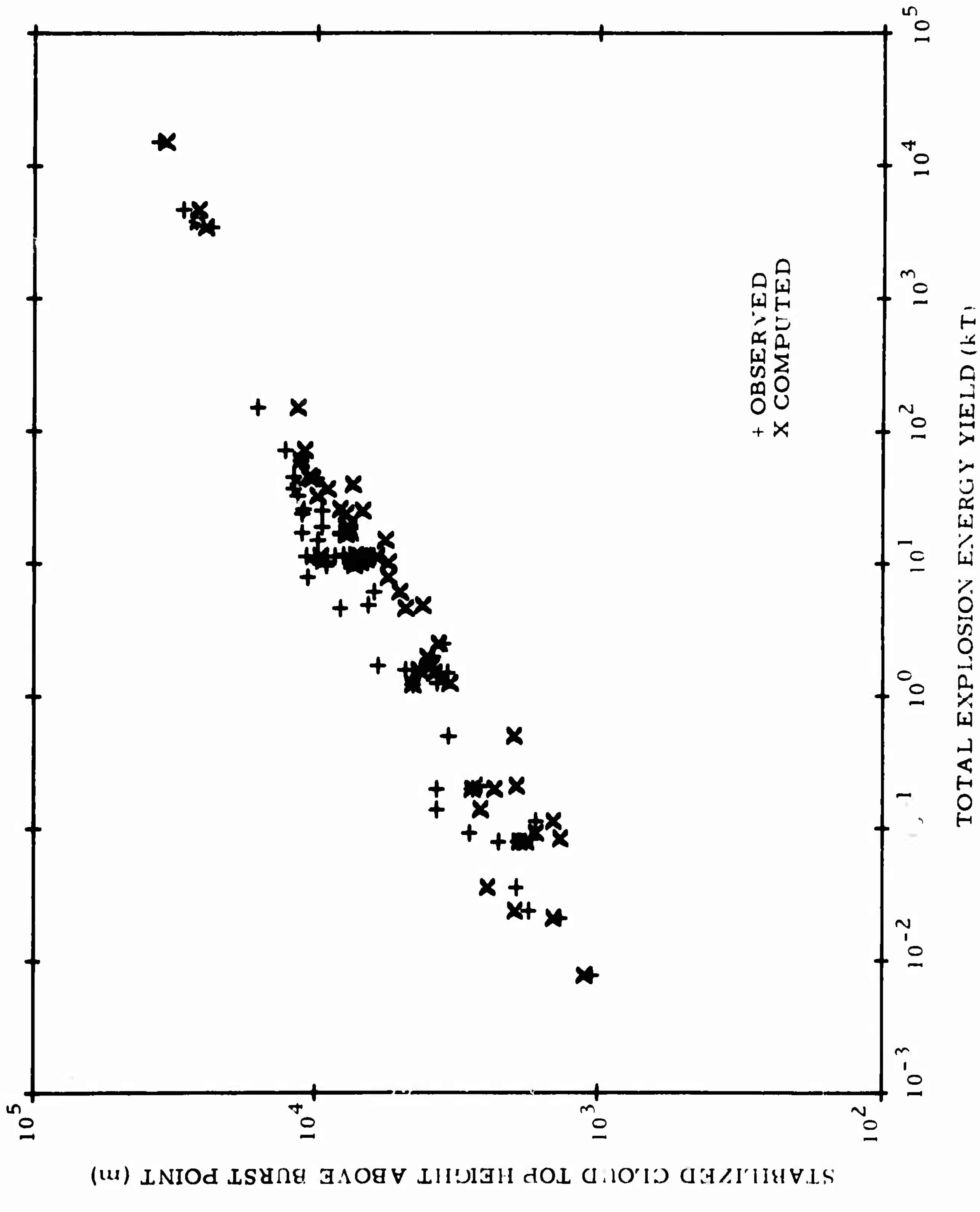


Figure A.2.1. Simulated and Observed Stabilized Cloud Top Heights Versus Yield

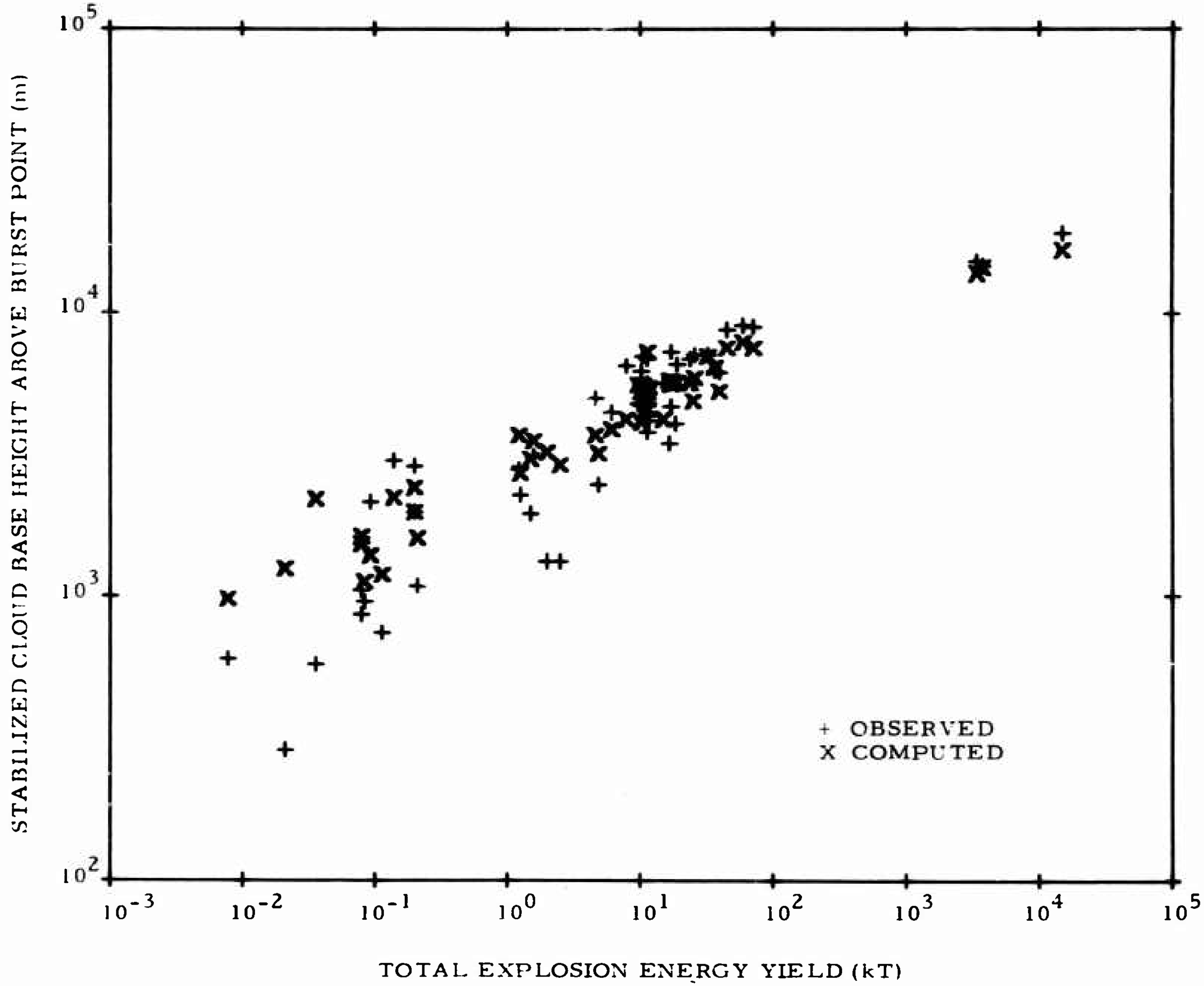


Figure A.2.2. Simulated and Observed Stabilized Cloud Base Heights Versus Yield

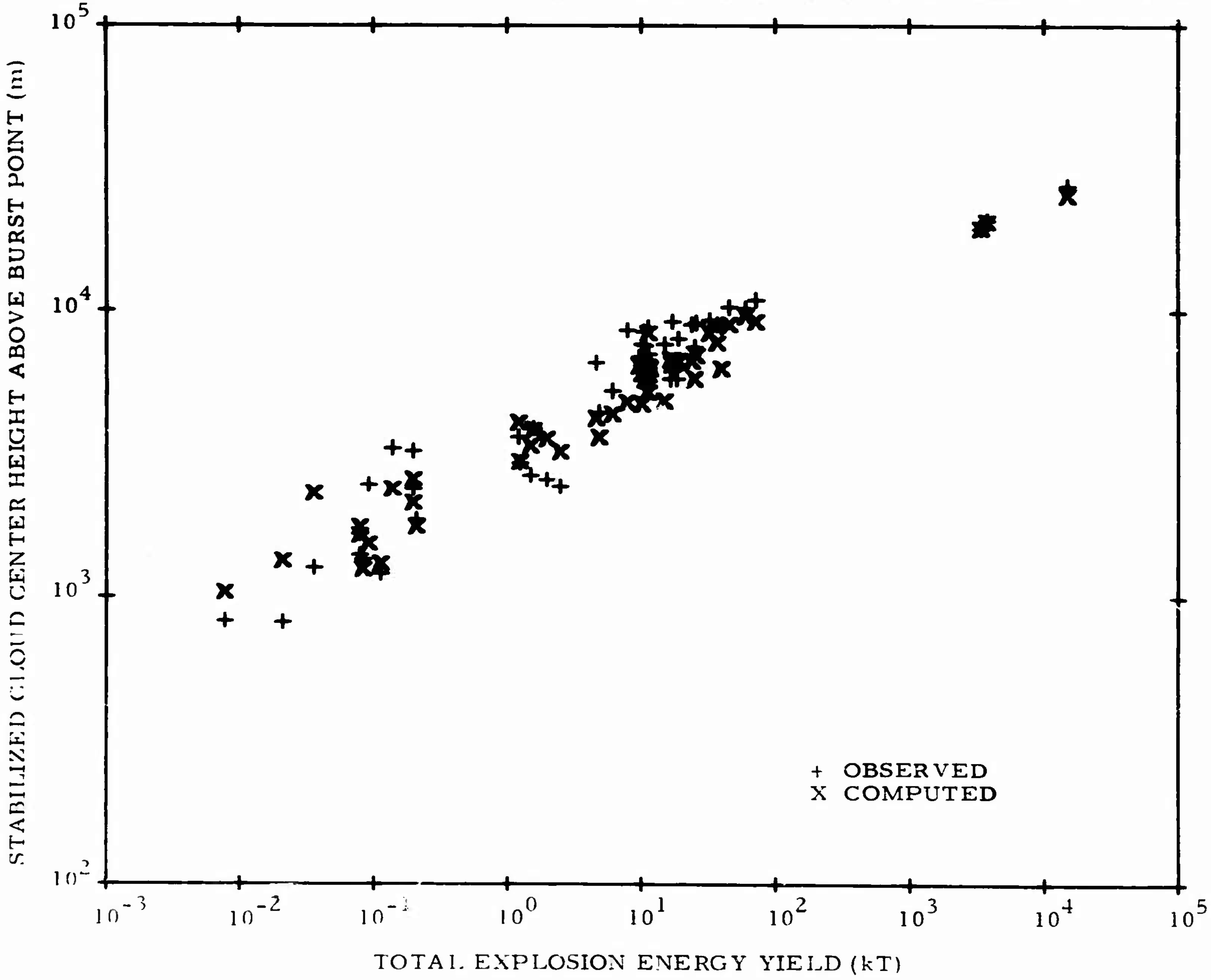


Figure A.2.3. Simulated and Observed Cloud Center Heights Versus Yield

TABLE A.2.1

OBSERVED AND COMPUTED CLOUD TOP, BASE AND CENTER HEIGHTS
OBSERVED
COMPUTED

Shot	Yield (kT)	Top Height (m)	Base Height (m)	Center Height (m)
HJ-33	7.8×10^{-3}	1050.0 1104.1	592.8 974.8	821.4 1039.4
HJ-25	2.1×10^{-2}	1350.2 1431.3	283.4 1240.6	816.8 1335.0
HJ-18	2.4×10^{-2}	1759.9 1969.4	—— 1739.7	—— 1854.6
HJ-17	3.6×10^{-2}	1939.7 2489.8	568.1 2161.6	1253.9 2325.7
HJ-9	7.85×10^{-2}	2266.7 1790.4	1047.5 1507.5	1657.1 1648.9
HJ-3	8.0×10^{-2}	1924.5 1900.2	857.7 1602.7	1391.1 1751.5
HJ-12	8.4×10^{-2}	1722.4 1355.6	960.4 1124.2	1341.4 1239.9
HJ-19	9.2×10^{-2}	2870.6 1659.2	2108.6 1386.8	2489.6 1523.0
HJ-22	1.15×10^{-1}	1652.9 1437.1	738.5 1181.9	1195.7 1309.5
P-3	1.4×10^{-1}	3771.5 2620.0	2948.6 2198.7	3360.1 2409.3
P-22	1.97×10^{-1}	3739.8 2834.5	2825.4 2360.1	3282.6 2597.3
UK-3	2.0×10^{-1}	2833.1 2353.8	1949.1 1945.5	2391.1 2149.7

TABLE A.2.1 (cont.)

OBSERVED AND COMPUTED CLOUD TOP,
BASE AND CENTER HEIGHTS
OBSERVED
COMPUTED

Shot	Yield (kT)	Top Height (m)	Base Height (m)	Center Height (m)
UK-5	2.1×10^{-1}	2642.6 1944.3	1088.1 1590.3	1865.3 1767.3
SB-2	5.0×10^{-1}	3444.2 1989.4	——— 1611.0	——— 1800.2
P-24	1.22×10^{0}	4591.5 4564.8	2762.7 3633.9	3677.1 4099.4
HJ-34	1.25×10^{0}	3753.3 3400.7	2229.3 2666.6	2991.3 3033.6
HJ-13	1.5×10^{0}	3448.5 3827.2	1924.5 2996.6	2686.5 3411.9
P-10	1.73×10^{0}	6004.5 3933.4	——— 3016.4	——— 3474.9
HJ-8	2.0×10^{0}	3904.4 4095.0	1314.9 3177.8	2609.7 3636.4
HJ-29	2.5×10^{0}	3600.9 3727.4	1314.9 2847.8	2457.9 3287.6
P-19	4.7×10^{0}	8249.1 4843.4	4896.3 3648.7	6572.7 4246.0
HJ-28	4.9×10^{0}	6529.7 4207.8	2414.9 3136.6	4472.3 3672.2
HJ-21	6.2×10^{0}	6206.9 5080.2	4378.1 3783.9	5292.5 4432.1
P-30	8.0×10^{0}	10755.1 5582.2	6487.9 4130.5	8621.5 4856.3

TABLE A.2.1 (cont.)

OBSERVED AND COMPUTED CLOUD TOP,
BASE AND CENTER HEIGHTS
OBSERVED
COMPUTED

Shot	Yield (kT)	Top Height (m)	Base Height (m)	Center Height (m)
P-12	9.7×10^0	9230.8 7370.3	4658.8 5483.6	6944.8 6426.9
P-5	1.03×10^1	9226.2 5534.7	6178.2 4039.8	7702.2 4787.3
P-11	1.03×10^1	7068.6 7000.1	4630.2 5178.9	5849.4 6089.5
UK-4	1.05×10^1	10043.1 7476.7	6995.1 5521.7	8519.1 6499.2
P-17	1.07×10^1	9835.8 6719.6	5263.8 4948.2	7549.8 5833.9
P-25	1.14×10^1	10811.2 6969.5	6848.8 5130.5	8830.0 6050.0
P-29	1.14×10^1	8011.6 6099.6	4354.0 4451.1	6182.8 5275.4
P-21	1.15×10^1	9829.8 6619.1	3733.7 4856.1	6781.8 5737.6
P-2	1.15×10^1	8615.1 9684.8	5567.1 7233.1	7091.1 8458.9
P-26	1.18×10^1	8020.5 7272.0	4058.1 5350.3	6039.3 6311.1
UK-10	1.5×10^1	9875.5 5719.3	5547.3 4100.1	7711.4 4909.7
P-16	1.65×10^1	8264.3 7832.7	3387.5 5691.0	5825.9 6761.8

TABLE A.2.1 (cont.)

OBSERVED AND COMPUTED CLOUD TOP, BASE AND CENTER HEIGHTS
OBSERVED
COMPUTED

Shot	Yield (kT)	Top Height (m)	Base Height (m)	Center Height (m)
P-9	1.7×10^1	8239.0 7606.6	4581.4 5508.4	6410.2 6557.5
UK-1	1.71×10^1	11177.0 7865.8	7214.6 5711.3	9195.8 6788.5
P-28	1.85×10^1	7624.2 7713.6	3966.6 5565.9	5795.4 6639.8
P-14	1.9×10^1	9544.5 7802.9	6496.5 5621.7	8020.5 6712.3
UK-2	2.4×10^1	11244.0 7810.3	6824.4 5566.5	9034.2 6688.4
UK-6	2.5×10^1	9512.8 6809.5	5550.4 4797.2	7531.6 5803.3
UK-8	2.6×10^1	11125.1 8230.7	7101.8 5846.5	9113.5 7038.6
UK-9	3.23×10^1	11640.3 9847.6	7068.3 6996.9	9354.3 8422.2
P-6	3.66×10^1	11955.4 9135.0	6164.2 6413.5	9059.8 7774.3
RW-1	3.95×10^1	11582.0 7410.2	6096.0 5180.3	8839.0 6295.3
P-20	4.4×10^1	10003.8 10370.4	——— 7248.5	——— 8809.5
UK-7	4.5×10^1	12027.0 10647.6	8680.7 7458.0	10353.9 9052.8

TABLE A.2.1 (cont.)

OBSERVED AND COMPUTED CLOUD TOP, BASE AND CENTER HEIGHTS
OBSERVED
COMPUTED

Shot	Yield (kT)	Top Height (m)	Base Height (m)	Center Height (m)
UK-11	6.0×10^{1}	11381.5 11384.6	9034.5 7852.4	10208.0 9618.5
P-8	7.1×10^{1}	12883.8 11013.5	8921.4 7502.0	10902.6 9257.8
C-3	1.5×10^{2}	16154.4 11552.9	——— 7627.1	——— 9590.0
RW-3	3.38×10^{3}	24079.1 25195.3	14935.1 13623.3	19507.1 19409.3
RW-16	4.6×10^{3}	30175.1 26613.4	——— 14017.4	——— 20315.4
C-1	1.5×10^{4}	36576.0 34821.9	18897.6 16492.9	27736.8 25657.4

Key: HJ is Hardtack II
P is Plumbob
UK is Upshot Knothole
SB is Sunbeam
RW is Redwing
C is Castle

The shot numbers are those given in DASA-1251, Volume II.

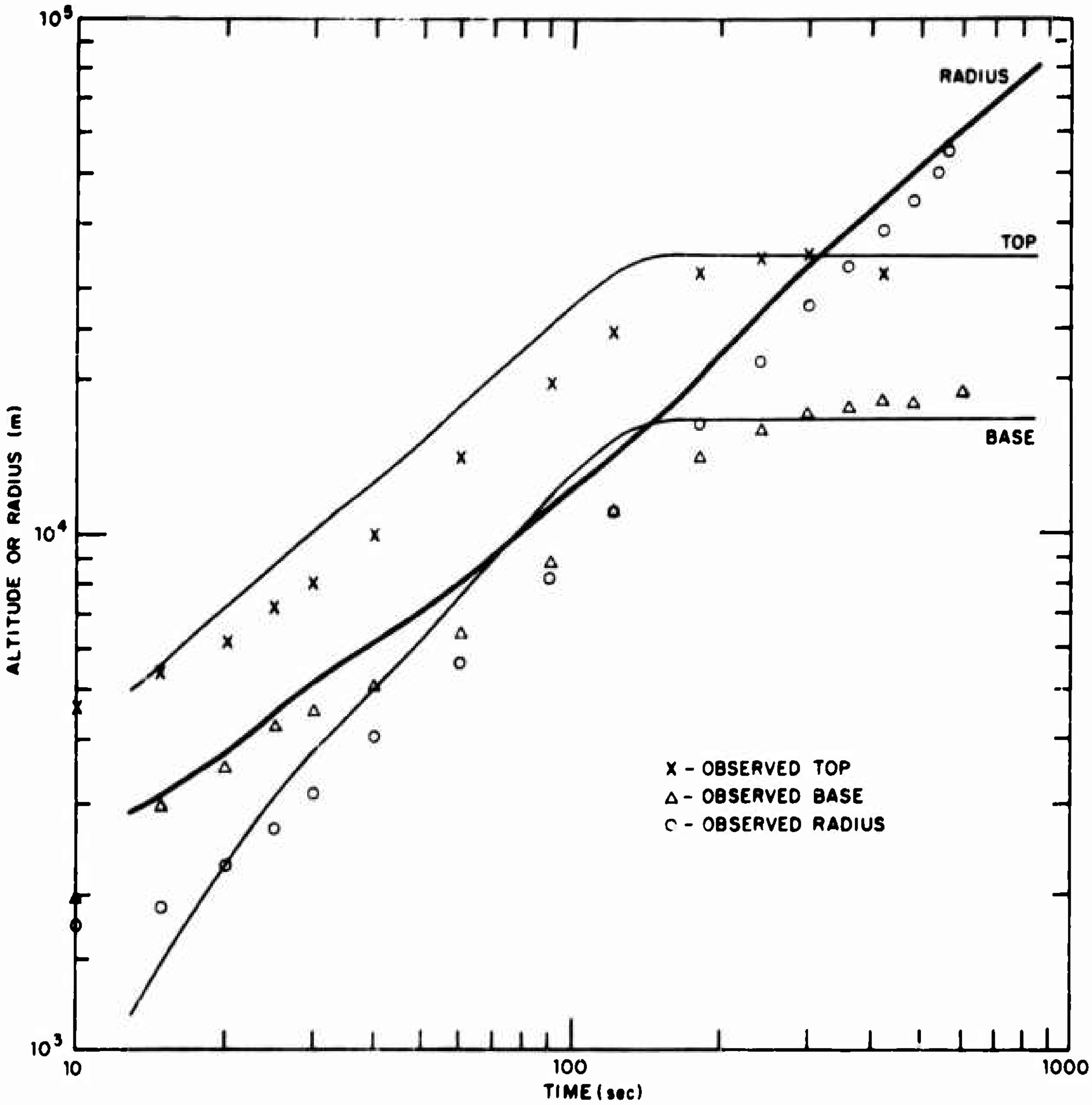


Figure A.2.4. Simulated and Observed Cloud Rise History Data for a 15MT Surface Shot

REFERENCES

A.2.1 P.D. LaRiviere, et al. "Local Fallout from Nuclear Test Detonations. Vol. V. Transport and Distribution of Local (Early) F llout from Nuclear Weapons Tests", DASA-1251, NDL-TR-65, SRI-4-3338 (May 1965). Secret-R.D. AD 362 012.

A.2.2 Unpublished Document on Cloud Characteristics, Edgerton, Germeshausen, and Grier Report No. ET-833, prepared on Contract AT(29-1)1183. Secret-F.R.D.

PART 3

CLOUD RISE-TRANSPORT INTERFACE MODULE

INTRODUCTION

The function of this module of the DELFIC system is to provide liaison between the cloud rise and atmospheric transport portions of the system. It is available to perform whatever data modification and/or processing is required to accomplish this. In its present form the system demands relatively little of this module. The module is used to accept some additional data and to adjust the fallout parcel positions to account for wind transport during the time period of the cloud rise.

In this revised version of the CRTIM, we have deleted the "option (b)" capability that was included in the previous version of subroutine LINK4. That is, the module no longer can accommodate a particle input that varies spatially in two dimensions in a continuous fashion. Also, only one binary particle output, the wind-drift corrected output, now is prepared. Subroutine WNDSFT has been revised and reprogrammed in many parts. This has been done to increase the accuracy of its results. Functionally, it is intended to serve the same purpose as before.

METHOD OF CALCULATION

Using the binary output of the Cloud Rise Module, which is contained on logical storage unit IRISE, subroutine WNDSFT corrects the x and y coordinates of each fallout parcel for wind-drift during the time period of the cloud rise.

To perform the wind-drift corrections we require a table of wind vectors as a function of altitude over ground zero, the altitude profile of atmospheric viscosity and density (to be used for particle settling rate calculations), and tables of cloud bottom altitude, top altitude, bottom rise velocity, top rise velocity, and the corresponding times. All of these data are contained in the input from the Cloud Rise Module. With this information we can separate the problem into two parts: (1) the calculation of the lateral displacement of those parcels that leave the cap to form the stem, and (2) the lateral displacement of those parcels that remain in the cap. For the latter part we simply compute a table of cloud center displacements as a function of time. This table will then supply wind-drift displacements for all parcels (i.e., cloud subdivisions) during their time of residence in the cloud cap. For stem parcels the calculations are more complex. In the calculations described here, the vertical thickness of the fallout parcels is ignored; we consider their altitudes to be given by the point positions of their centers of mass. Let us consider first the calculations of displacements for the cloud cap.

We compute the lateral drift of the cap by allowing the winds at each stratum of atmosphere, as defined by the wind data table, to act on the cap during the time the cap is in that stratum according to

$$\Delta x_j = v_{x_j} \Delta t_j , \quad \Delta y_j = v_{y_j} \Delta t_j ,$$

where Δx_j and Δy_j are the components of the cap center displacement in the jth stratum of the atmosphere, v_{x_j} and v_{y_j} are the components of the wind velocity in the jth stratum, and Δt_j is the time the cloud spends in the jth stratum. The total displacement of the cap $\underset{\sim}{D}$ is

$$\underset{\sim}{D} = \sum_j \left(\Delta x_j \underset{\sim}{u}_x + \Delta y_j \underset{\sim}{u}_y \right) , \tag{3.1}$$

where $\underset{\sim}{u}_x$ and $\underset{\sim}{u}_y$ are unit vectors in the x and y directions. This displacement is applied to all parcels whose final z coordinates are equal to, or greater than, the final cloud bottom altitude.

To explain the wind-drift calculations for parcels that have fallen through the cloud bottom during the cloud rise, we refer to Figure 3.1. Let the time and altitude coordinates of the parcel (i.e., cloud subdivision), as they are input to the CRTIM, be t_b and z_b. In the figure, the cloud bottom time history is given by the solid curve and the time and altitude at which the parcel passed through the cloud bottom are t_a and z_a. WNDSFT computes the parcel settling motion backward in time (i.e., upward through the atmosphere below the cloud), while over the same time increments it steps backward through the cloud rise history table to determine the cloud bottom altitudes. In this way, the parcel and cloud bottom altitudes finally converge, and thus the time, t_a, is determined. During this back calculation, time steps are chosen to be the lesser of the time intervals required, on the one hand, for the parcel to traverse a wind hodograph stratum, or on the other, for the cloud bottom to advance downward one cloud history table time increment. For each time step, wind-drift increments are added to the overall displacement components for the parcel. For the time increment between the cloud rise calculation initial time, t_i, and t_a, displacement increments are determined from the cloud cap trajectory table by linear interpolation and these are added to the below cloud displacements.

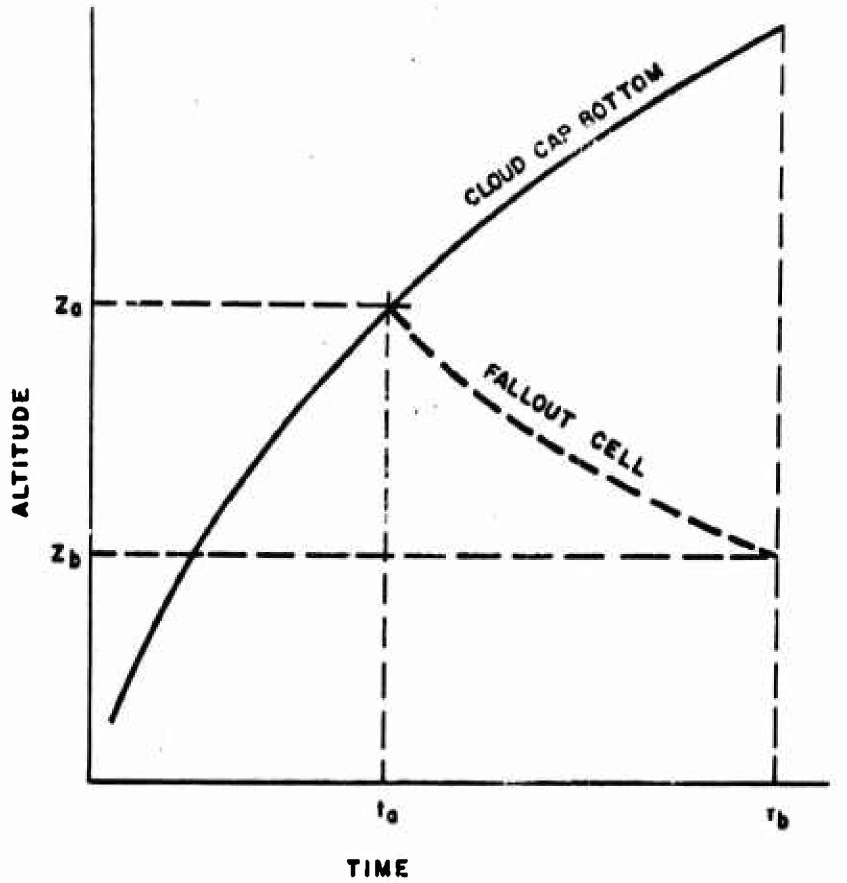


Figure 3.1 Time-Altitude Relationship of the Cloud Cap Bottom and a Fallout Parcel Trajectory

The parcel time coordinates, t_b, are not all equal, but if a particle is still air borne when input to the CRTIM, t_b will equal the Cloud Rise Module calculation termination time (i.e., the effective cloud stabilization time). For parcels on the ground, however, t_b is the time of impact. With this time information available, subroutine WNDSFT can compute wind-drift adjustments for grounded particles as well as for air-borne particles.

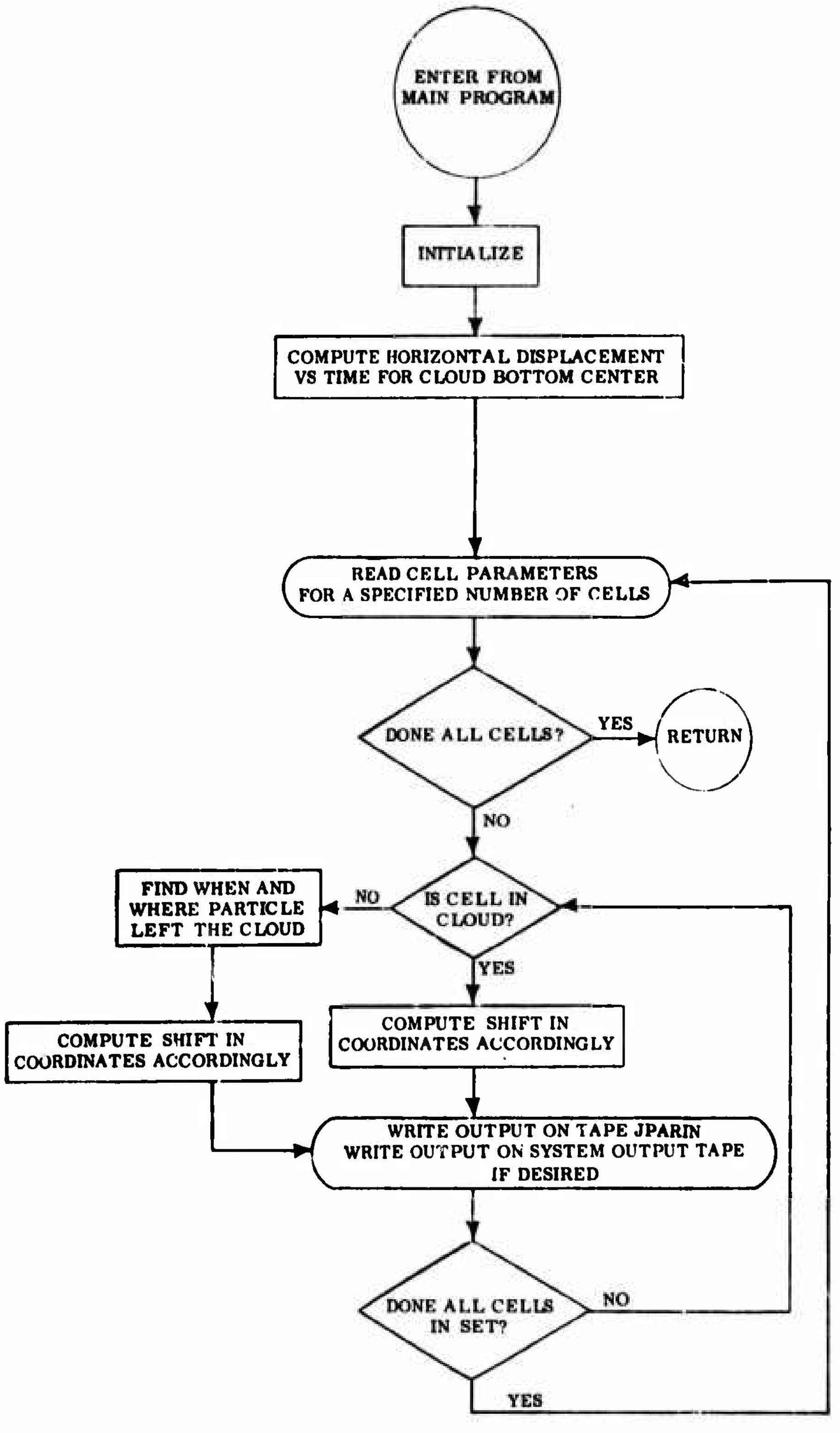
During the Cloud Rise Module calculations, the origin of space coordinates is at mean sea level in the vertical and at ground zero in the horizontal. Time is relative to detonation time. In the CRTIM, time and horizontal space coordinates of all fallout parcels can be translated to refer to user specified origins.

PROGRAM DESCRIPTION

The Cloud Rise - Transport Interface Module consists of two major subroutines: an executive program LINK4, and WNDSFT. Subroutine LINK4 is a very simple program that does no more than: (1) read the header data from the Cloud Rise Module output unit, IRISE; (2) read from the operating system input unit the CRTIM run identification, an array of control integers, and, the x, y, and t translation components, XGZ, YGZ, TGZ, to be added to the corresponding coordinates of each fallout parcel; (3) write the header data on the CRTIM binary output unit, JPARIN; and (4) call subroutine WNDSFT.

Subroutine WNDSFT adjusts the horizontal coordinates of all of the fallout parcels as described in the Method of Calculation section. The wind data read by LINK1 are used. After the horizontal coordinates are adjusted for wind drift,and these coordinates and the time are translated by amounts XGZ, YGZ, and TGZ, the parcel data are copied onto the CRTIM binary output tape, JPARIN, and also printed, if printing has been requested. Flow chart FC-3.1 gives an organizational view of logical flow through subroutine WNDSFT.

Logical output unit JPARIN is written in the binary mode and is given the identifier name JPARIN. Its contents are described in detail in the User Information section. In addition to subroutines LINK4 and WNDSFT, the CRTIM also uses subroutines ERROR and FALRAT, the general utility error program and the particle settling rate program. These subroutines are described in DASA-1800-VII and DASA-1800-IV respectively.



FC-3.1. Organizational Chart of Subroutine WNDSFT

USER INFORMATION

INPUT

Inputs to the Cloud Rise-Transport Interface Module (CRTIM) are of three categories:

1. Inputs from COMMON core storage via COMMON/SET 1/.
2. Inputs from a binary mode storage unit, logical designation IRISE, that contains outputs of a cloud rise calculation.
3. Inputs from cards via the operating system input unit.

COMMON/SET 1/Input

COMMON/SET 1/ and its contents have been described in detail in Part 2 (see Table 2.2). There are no changes made in the COMMON/SET 1/ contents in the CRTIM.

Binary Tape Inputs

The binary input to the CRTIM is fully described in Table 2.5 of Part 2 and does not require further amplification here.

Card Inputs

Card inputs to the CRTIM are described in detail in Table 3.1. Cards 2 and 3, however, require additional explanation.

In its present form only two of the 18 elements of the control parameter array IC(J) is in use. These are IC(3) and IC(4). A value of IC(3) ≠ 0 causes the particle contents of tapes IRISE and JPARIN to be printed. A value of IC(3) = 0 causes the printing of these tapes to be omitted (see the discussion in the Output section). A values of IC(4) ≠ 0 produces an output of working values of parameters in subroutine WNDSFT. These outputs are placed in the program after statement numbers 278, 300, and 320 and occur after each passage through these statements. The data produced are useful for trouble-shooting in subroutine WNDSFT.

Up to the time of the CRTIM calculations all x and y coordinates are relative to ground zero and time is relative to detonation time. By means of card 3, the x, y, and t coordinates of all particles can be shifted (via addition of XGZ, YGZ, and TGZ) to a different origin.

TABLE 3.1

CRTIM INPUT DATA FROM THE OPERATING SYSTEM INPUT UNIT

Card Number	Content	Variable Names and Formats
1	CRTIM identification card.	PSEID(J), J=1, 12 (12A6)
2	Control indices. All IC(J) = 0 except IC(3). If IC(3) ≠ 0, the complete particle output (both unskewed and skewed clouds) will appear on the system output unit. If IC(3) = 0, only unit JPARIN will be written. As the CRTIM program output is voluminous, we suggest setting IC(3) = 0 to save computation time. If IC(4) ≠ 0 a special trouble-shooting output is printed by subroutine WNDSFT (see text).	IC(J), J=1, 18 (18I4)
3	x and y coordinates of ground zero (m), and detonation time (sec).	XGZ, YGZ, TGZ (3E12.5)

OUTPUT

Printed output from the CRTIM is essentially completely labeled and needs little discussion here. An example of this output is provided in the Sample Problem and Print Out section. All of the essential input data are printed including the particle size class data, atmosphere tables, and the cloud trajectory table calculated in subroutine WNDSFT. In addition, if control parameter IC(3) is not zero, the complete particle contents of both tapes IRISE and JPARIN are printed. Since this latter output is voluminous, we suggest that it be requested only for debugging purposes. To eliminate this output, assign IC(3) = 0. The trouble-shooting output produced by subroutine WNDSFT when IC(4) ≠ 0 is useful only to the programmer-analyst who is intimately familiar with the code and its functions. It should never be requested during routine use of the code.

Contents of the binary CRTIM output unit JPARIN is described in Table 3.2.

TABLE 3.2

CRTIM BINARY OUTPUT (UNIT JPARIN)

Record Number	Content	Variable Names
1	Tape identification word (JPARIN)	DENTI
2	Fission yield (kT), mass of the cloud soil burden (kg), soil solidification temperature (^{o}K), time at which the cloud reached the soil solidification temperature (sec), geometric standard deviation of the lognormal particle-diameter volume-frequency distribution, total yield (kT), height of burst above msl(m), x coordinate (E-W) of GZ(m), y coordinate (N-S) of GZ(m), detonation time (sec), base edge length of the basic cloud sub-division (m), fallout particle density (kg/m^3), the horizontal cloud sub-division parameter IRAD, maximum cloud radius (m), height of ground zero above msl(m).	FW, SSAM, SLDTMP, TMSD, SD, TW, HEIGHT, XGZ, YGZ, TGZ, BZ, ROPART, IRAD, RADMAX, ZBRSTZ
3	CRTIM run identification	PSEID(I), I = 1, 12
4	Cloud Rise Module run identification	CRID(I), I = 1, 12
5	Initial Conditions Module run identification	DETID(I), I = 1, 12
6	Number of particle size classes	NDSTR
7	Particle size class tables: central particle diameter (μm), volume (mass) fraction, particle diameter at the upper boundary of the size class (μm).	PS(I), FMASS(I), DIAM(I), I = 1, NDSTR
8	Number of (altitude) entries in the atmosphere description tables	NAT (=256)
9	Atmosphere tables: viscosity (kg/(m-sec)), density (kg/m^3)	ATEMP(I), RHO(I), I = 1, NAT

TABLE 3.2 (con't.)

CRTIM BINARY OUTPUT (UNIT JPARIN)

Record Number	Content	Variable Names
10	Parcel description block count	NP
11	Block of parcel (cloud subdivision) descriptions: x, y, and t coordinates (m and sec), size class central diameter(m), mass of fallout in the parcel (kg), altitude of parcel center of mass above msl(m), parcel radius (m), vertical thickness of parcel (m), altitude of parcel base above msl (m), parcel volume (m^3).	XPAR(I), YPAR(I), TP(I), PSIZ(I), PMAS(I), ZPAR(I), RWAF(I), DWAF(I), ZLOW(I), VWAF(I), I = 1, NP
12	Block count	
13	Block of parcel descriptions	
.		
.		
.		
.		
14	Zero block count	NP = 0

FORTRAN LISTINGS

The FORTRAN listings are included on pp. 180 through 192. Note that the glossary of mnemonics for both subroutines LINK4 and WNDSFT is at the beginning of subroutine LINK4 (p. 180).

LIST OF FORTRAN LISTINGS

```
      SUBROUTINE LINK4 (NOMINAL)                                        LINK4001
C     CLOUD RISE - TRANSPORT INTERFACE MODULE MAIN PROGRAM              LINK4002
C     ARCON REVISION   2 FEB. 1970                                      LINK4003
C     ATEMP(I)    DYNAMIC VISCOSITY OF AIR AT (I-1)*200 METERS ABOVE MSL LINK4004
C                 IN KILOGRAMS PER METER-SECOND                         LINK4005
C     BZ          EDGE LENGTH (METERS) OF A BASIC SQUARE BASED CLOUD CELLLINK4006
C     CRID(J)     CLOUD RISE IDENTIFICATION CARD.   J=1,12              LINK4007
C     DENT        BCD NAME OF TAPE FROM CLOUD RISE PROGRAM, DENT = IRISE LINK4008
C     DETID(J)    DETONATION IDENTIFICATION CARD.   J=1,12              LINK4009
C     DIAM(I)     ARRAY(201), UPPER BOUNDARY OF THE I-TH PARTICLE SIZE  LINK4010
C                 CLASS. THE LAST ENTRY IN THE DIAM ARRAY IS THE LOWER  LINK4011
C                 BOUNDARY OF THE LAST(SMALLEST) PARTICLE SIZE CLASS.   LINK4012
C                 THE LENGTH OF THE DIAM ARRAY IS ALWAYS ONE GREATER THANLINK4013
C                 THE NUMBER OF SIZE CLASSES. (MICROMETERS)             LINK4014
C     DWAF(I)     WAFER VERTICAL THICKNESS (METERS)                     LINK4015
C     DX          WIND-SHIFT CORRECTION TO BE ADDED TO THE PARTICLE X   LINK4016
C                 COORDINATE                                            LINK4017
C     DY          WIND-SHIFT CORRECTION TO BE ADDED TO THE PARTICLE Y   LINK4018
C                 COORDINATE                                            LINK4019
C     FV          STILL AIR PARTICLE SETTLING RATE                      LINK4020
C     FW          FISSION YIELD (KT)                                    LINK4021
C     HEIGHT      HEIGHT OF BURST (METERS) ABOVE GROUND ZERO            LINK4022
C     IC(J)       CONTROL INDICES.   J=1,18                             LINK4023
C                    IC(3)=0  DO NOT PRINT LISTS OF PARTICLE OUTPUTS    LINK4024
C                    IC(3)=1  PRINT COMPLETE LISTS OF PARTICLE OUTPUTSFORLINK4025
C                             BOTH THE AXIALLY SYMMETRIC AND WIND       LINK4026
C                             DISTORTED CLOUDS                          LINK4027
C     IRISE       LOGICAL NUMBER AND IDENTIFICATION NAME OF THE CLOUD   LINK4028
C                 RISE MODULE OUTPUT TAPE                               LINK4029
C     IRROR       NUMBER OF STATEMENT NEAR WHERE AN ERROR WAS DISCOVERED LINK4030
C     ISIN        NUMBER OF SYSTEM INPUT TAPE                           LINK4031
C     ISOUT       NUMBER OF SYSTEM OUTPUT TAPE                          LINK4032
C     JPARIN      LOGICAL NUMBER OF TAPE ON WHICH IS WRITTEN PARTICLE   LINK4033
C                 POSITIONS ADJUSTED FOR TRANSPORT BY WINDS DURING CLOUD LINK4034
C                 RISE                                                  LINK4035
C     MHODO       NHODO-1                                               LINK4036
C     MPOSIT      NPOSIT+1                                              LINK4037
C     NAT         NUMBER OF ALTITUDE   STRATA IN THE ATMOSPHERE TABLES, LINK4038
C                   NAT=256                                             LINK4039
C     NHODO       NUMBER OF ELEMENTS IN THE WIND HODOGRAPH              LINK4040
C     NPOSIT      NUMBER OF TIME ENTRIES IN THE CLOUD RISE HISTORY TABLESLINK4041
C                 CX (SEE DASA-1800-III)                                LINK4042
C     PMAS(I)     TOTAL PARTICULATE MASS (KGM) OF WAFER                 LINK4043
C     PROGRM      BCD NAME OF PROGRAM                                   LINK4044
C     PS(J)       CENTRAL PARTICLE DIAMETER (MICRONS) OF THE J TH       LINK4045
C                 PARTICLE SIZE CLASS                                   LINK4046
C     PSEID(J)    RUN IDENTIFICATION FOR THE CLOUD RISE - TRANSPORT     LINK4047
C                 INTERFACE MODULE.    J=1,12                           LINK4048
C     PSIZ(I)     MIDPOINT (METERS) OF WAFER PARTICLE SIZE CLASS        LINK4049
C     RADMAX      MAXIMUM CLOUD RADIUS (METERS)                         LINK4050
C     RHO(I)      ATMOSPHERIC DENSITY AT (I-1)*200 METERS ABOVE MSL IN  LINK4051
C                 KILOGRAMS PER CUBIC METER                             LINK4052
C     ROPART      SOIL (PARTICLE) DENSITY IN KILOGRAMS PER CUBIC METER  LINK4053
C     RV          UPWARD COMPONENT OF VELOCITY OF A STEM PARTICLE       LINK4054
C     RWAF(I)     RADIUS (METERS) OF WAFER AT CENTER OF MASS            LINK4055
C     SD          PARTICLE SIZE GEOMETRIC STANDARD DEVIATION            LINK4056
C                 (DIMENSIONLESS)                                       LINK4057
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C       SLDTMP       SOLIDIFICATION TEMPERATURE (DEG. K) OF SOIL            LINK4058
C       SSAM         MASS (KG) OF THE CLOUD SOIL BURDEN                     LINK4059
C       TC(I)        TIME(RELATIVE TO DETONATION OF)THE I-TH CLOUD RISE     LINK4060
C                    TABLE ENTRY                                            LINK4061
C       TCUR         PARTICLE TIME COORDINATE DURING A WIND DRIFT           LINK4062
C                    ADJUSTMENT CALCULATION INCREMENT                       LINK4063
C       TGZ          TIME OF DETONATION                                     LINK4064
C       TMSD         TIME(SEC) RELATIVE TO SHOT TIME AT WHICH THE CLOUD     LINK4065
C                    REACHED THE SOIL SOLIDIFICATION TEMPERATURE            LINK4066
C       TP(I)        TIME OF DEFINITION (SEC) OF THE I TH CLOUD CELL        LINK4067
C       TW           TOTAL YIELD (KT)                                       LINK4068
C       VB(I)        CLOUD BOTTOM VEL.  OF THE I-TH CLOUD RISE TABLE ENTRY  LINK4069
C       VC(I)        VELOCITY ASSOCIATED WITH CLOUD AT ZC(I) AT TC(I).  I=1,LINK4070
C                    NPOSIT                                                 LINK4071
C       VT(I)        CLOUD TOP VELOCITY OF THE I-TH CLOUD RISE TABLE ENTRY  LINK4072
C       VX(I)        X WIND COMPONENT OF THE ITH WIND STRATUM               LINK4073
C       VY(I)        Y WIND COMPONENT OF THE ITH WIND STRATUM               LINK4074
C       VWAF(I)      WAFER VOLUME (CUBIC METERS)                            LINK4075
C       XC(I)        X COORDINATE OF THE CLOUD CAP CENTER FOR THE ITH CLOUD LINK4076
C                    RISE TABLE ENTRY AFTER WIND SHIFT ADJUSTMENT           LINK4077
C       XGZ          X COORDINATE OF GROUND ZERO    (METERS)                LINK4078
C       XPAR(I)      X COORDINATE OF CELL I WRITEN ON THE OUTPUT TAPES      LINK4079
C                    (METERS)                                               LINK4080
C       YC(I)        Y COORDINATE OF THE CLOUD CAP CENTER FOR THE ITH CLOUD LINK4081
C                    RISE TABLE ENTRY AFTER WIND SHIFT ADJUSTMENT           LINK4082
C       YGZ          Y COORDINATE OF GROUND ZERO (METERS)                   LINK4083
C       YPAR(I)      Y COORDINATE OF CELL I WRITEN ON THE OUTPUT TAPES      LINK4084
C                    (METERS)                                               LINK4085
C       ZB(I)        CLOUD BOTTON ALT.  OF THE I-TH CLOUD RISE TABLE ENTRY  LINK4086
C                    (METERS ABOVE MSL)                                     LINK4087
C       ZBRSTZ       ELEVATION OF GROUND ZERO(METERS ABOVE MSL)             LINK4088
C       ZC(I)        CLOUD CENTER ALT.  OF THE I-TH CLOUD RISE TABLE ENTRY  LINK4089
C                    (METERS ABOVE MSL)                                     LINK4090
C       ZCUR         PARTICLE ALTITUDE AT THE BEGINNING OF A WIND DRIFT     LINK4091
C                    ADJUSTMENT CALCULATION INCREMENT                       LINK4092
C       ZLOW(I)      ALTITUDE OF WAFER BOTTOM (METERS)                      LINK4093
C       ZPAR(I)      Z COORDINATE OF CELL I WRITEN ON THE OUTPUT TAPES      LINK4094
C                    (METERS ABOVE MSL)                                     LINK4095
C       ZT(I)        CLOUD TOP ALTITUDE OF THE I-TH CLOUD RISE TABLE ENTRY  LINK4096
C                    (METERS ABOVE MSL)                                     LINK4097
C       ZTEMP        TEMPORARY STORAGE OF THE Z COORDINATE OF THE 1ST SMALL LINK4098
C                    CELL WITHIN EACH LARGE CELL                            LINK4099
C                                                                           LINK4100
C **********************************************************************LINK4101
C **********************************************************************LINK4102
      COMMON /SET1/                                                         LINK4103
     1CAY      ,DETID(12) ,DIAM(201) ,DMEAN     ,DNS       ,EXPO      ,LINK4104
     2FMASS(200),IDISTR    ,IEXEC     ,IRISE     ,ISIN      ,ISOUT     ,LINK4105
     3NDSTR    ,PS(200)   ,SD        ,SSAM      ,TME       ,TMP1      ,LINK4106
     4TMP2     ,T2M       ,USOIL     ,VPR       ,W         ,HEIGHT    ,LINK4107
     5ZSCL     ,NHODO     ,ZV(200)   ,VX(200)   ,VY(200)              LINK4108
C **********************************************************************LINK4109
C                                                                           LINK4110
C       THIS PROGRAM PREPARES INPUT FOR THE TRANSPORT MODULE.  IT          LINK4111
C       CALLS SUBROUTINE WNDSFT WHICH APPLIES WINDS FOR THE PERIOD OF      LINK4112
C       CLOUD RISE AND PUTS THE RESULTING DATA IN TRANSPORTABLE FORM ONTO LINK4113
C       TAPE JPARIN.                                                        LINK4114
```

```
C
C ******************************************************************
C
      DIMENSION NUMTAP(15),CRID(12),PSEID(12),ATEMP(260),RHO(260),ZB(90)
     1,TC(90),VB(90),IC(18),ZT(90),VT(90),ALT(260)
C
C ******************************************************************
C
 9111 FORMAT(1H1///51X19H* * * * * * * * * *//12X101HT H E   D E P A R T
     1M E N T   O F   D E F E N S E   F A L L O U T   P R E D I C T I O
     2N   S Y S T E M,//51X,19H* * * * * * * * * *////41X,39HCLOUD RISE
     3 - TRANSPORT INTERFACE MODULE///
     4                          55X,11HPREPARED BY/53X,17HARCON CORPO
     5RATION/53X,16HWAKEFIELD, MASS.////)
    1 FORMAT(//
     116X,2HFW,12X,4HSSAM,10X,6HSLDTMP,8X,4HTMSD,10X,5HSIGMA/
     210X,5(E13.6,1X)//
     316X,2HTW,12X,3HHOB,11X,2HBZ,12X,6HROPART/
     410X,4(E13.6,1X)///
     510X,5HPSEID/10X,12A6//
     610X,4HCRID/10X,12A6//
     710X,5HDETID/10X,12A6///
     810X26HCONTROL ARRAY IC(J),J=1,18/10X,18I5///
     910X22HDETONATION COORDINATES,10X,3HXGZ,13X,3HYGZ,13X,3HTGZ/
     134X,3(E13.6,3X)////)
 2    FORMAT(10X,3HMPS, 9X,2HVI,11X,1HH,10X,3HCOL, 9X,4HCOLS, 8X,3HROW,
     1 9X,4HROWS, 7X, 4HCOLX,9X, 1HB/
     2                    8X,I5,4X,8(E11.4,1X))
 3052 FORMAT(/9X,'NDSTR = ',I5//17X,'PARTICLE SIZE',16X,'MASS FRACTION',
     118X,'SIZE CLASS'/17X,'(MICROMETERS)',40X,'UPPER BOUND(MICROMETERS)
     2')
 3087 FORMAT(//,1X,'KDPST = ',I5)
 3053 FORMAT(3(16X,E13.6))
 3054 FORMAT(1H1,9X,6HNAT = I5//21X,8HALTITUDE,20X,9HVISCOSITY,23X,3HRHO
     1)
 3055 FORMAT(3(16X,E13.6))
 3056 FORMAT(1H1, 9X,7HNPOSIT=I5//10X,5HTC(J),13X,5HZB(J),13X,5HZT(J),
     1 13X,5HVB(J),13X,5HVT(J))
 3057 FORMAT(5(5X,E13.6))
 1009 FORMAT(1X,A6,E13.6,I5)
 1011 FORMAT(12A6)
 1014 FORMAT(18I4)
 1015 FORMAT(3E12.5)
 1016 FORMAT(I5,4E13.6/4E13.6)
 1018 FORMAT(
     1                              15X, 2HXP,13X, 2HZP,12X, 3HIPS//
     2(7X,2(3X,E12.5),I10))
 1019 FORMAT(1X,2E13.6)
 1020 FORMAT(//29H  WRONG TAPE REEL ON DRIVE   I2,2X,41HPLEASE MOUNT COR
     1RECT TAPE AND PRESS START)
 3016 FORMAT(1X,I5,8E13.6)
C
C ******************************************************************
C ******************************************************************
C
      INTEGER DENTI,CHECK,DENT
      DATA DENTI,PROGRM/6HJPARIN,6HLINK4 /
```

```
      DATA CHECK /6H IRISE/
C     INITIALIZE
      JPARIN=NUMTAP(4)
C
C     PRINT OUTPUT HEADER
C
      WRITE(ISOUT,9111)
C
C     TEST TO SEE IF A WIND HODOGRAPH HAS BEEN PROVIDED--
C     IF NOT, TERMINATE THE CALCULATION
C
      IF(NHODO)100,100,200
  100 IRROR=-100
      CALL ERROR(PROGRM,IRROR,ISOUT)
      RETURN
C
C     READ ALL DATA FROM CLOUD RISE TAPE
  200 REWIND IRISE
  997 READ (IRISE)DENT
C
C     CHECK TO SEE THAT THE CORRECT CLOUD RISE TAPE (IRISE) HAS BEEN
C     MOUNTED
      IF(CHECK.EQ.DENT) GO TO 999
  998 PRINT 1020,IRISE
      WRITE (ISOUT,1020)IRISE
      REWIND IRISE
      PAUSE
      GO TO 997
  999 READ(IRISE)FW,SSAM,SLDTMP,TMSD,SD,TW,HEIGHT,BZ,ROPART,IRAD,
     1RADMAX,ZBRSTZ
      FROG = 1.30666667E-17*ROPART
      READ (IRISE)(CRID(J),J=1,12)
      READ (IRISE)(DETID(J),J=1,12)
      READ(IRISE)NDSTR
      READ(IRISE)(PS(I),FMASS(I),DIAM(I),I=1,NDSTR)
      READ(IRISE)KDPST
      READ (IRISE)NAT
      READ (IRISE)(ALT(I),ATEMP(I),RHO(I),I=1,NAT)
      READ (IRISE)NPOSIT
      READ(IRISE)(ZB(I),ZT(I),TC(I),VB(I),VT(I),I=1,NPOSIT)
      READ(IRISE)NHODO
      READ(IRISE)(ZV(J),VX(J),VY(J),J=1,NHODO)
C
C
C     CHANGE PARTICLE SIZE FROM METERS TO MICROMETERS
C
      DO 800 I=1,NDSTR
  800 PS(I)=PS(I)*1.0E6
C
C     READ ALL DATA FROM THE SYSTEM INPUT TAPE
 2000 READ (ISIN,1011)(PSEID(J),J=1,12)
      READ (ISIN,1014)(IC(J),J=1,18)
      READ (ISIN,1015)XGZ,YGZ,TGZ
C
C     WRITE A HARD COPY OF ALL INPUTS
 2005 WRITE (ISOUT,1) FW,SSAM,SLDTMP,TMSD,SD,TW,HEIGHT,BZ,ROPART,
     1(PSEID(J),J=1,12),(CRID(J),J=1,12),(DETID(J),J=1,12),(IC(J),J=1,
```

```
     2181,XGZ,YGZ,TGZ                                                   LINK4229
 2007 WRITE(ISOUT,3052)NDSTR                                            LINK4230
      WRITE(ISOUT,3053)(PS(J),FMASS(J),DIAM(J),J=1,NDSTR)               LINK4231
      WRITE(ISOUT,3087)KDPST                                            LINK4232
      WRITE(ISOUT,3054)NAT                                              LINK4233
      WRITE(ISOUT,3055)(ALT(J),ATEMP(J),RHO(J),J=1,NAT)                 LINK4234
      WRITE(ISOUT,3056)NPOSIT                                           LINK4235
      WRITE(ISOUT,3057)(TC(J),ZB(J),ZT(J),VB(J),VT(J),J=1,NPOSIT)       LINK4236
 2002 REWIND JPARIN                                                     LINK4237
      WRITE(JPARIN)DENTI                                                LINK4238
      WRITE(JPARIN)FW,SSAM,SLDTMP,TMSD,SD,TW,HEIGHT,XGZ,YGZ,TGZ,BZ,     LINK4239
     1ROPART,IRAD,RADMAX,ZBRSTZ                                         LINK4240
      WRITE(JPARIN)(PSEID(J),J=1,12)                                    LINK4241
      WRITE(JPARIN)(CRID (J),J=1,12)                                    LINK4242
      WRITE(JPARIN)(DETID(J),J=1,12)                                    LINK4243
      WRITE(JPARIN)NDSTR                                                LINK4244
      WRITE(JPARIN)(PS(J),FMASS(J),DIAM(J),J=1,NDSTR)                   LINK4245
      WRITE(JPARIN)NAT                                                  LINK4246
      WRITE(JPARIN)(ALT(J),ATEMP(J),RHO(J),J=1,NAT)                     LINK4247
C                                                                       LINK4248
C                                                                       LINK4249
C     CALL SUBROUTINE WNDSFT WHICH WILL SHIFT THE CLOUD IN ACCORDANCE   LINK4250
C     WITH THE PREVAILING WIND HODOGRAPH AND CREATE THE TAPE TO BE USED LINK4251
C     AS INPUT TO THE TRANSPORT MODULE                                  LINK4252
C                                                                       LINK4253
 2100 CALL WNDSFT(JPARIN,ATEMP,RHO,TC,ZB,VB,NPOSIT,XGZ,YGZ,TGZ,IC,FROG, LINK4254
     1CRID,ZT,VT,ZBRSTZ)                                                LINK4255
      RETURN                                                            LINK4256
      END                                                               LINK4257
```

```
      SUBROUTINE WNDSFT(JPARIN,ATEMP,RHO,TC,ZB,VB,NPOSIT,XGZ,YGZ,TGZ,IC,
     1FROG,CRID,ZT,VT,ZBRSTZ)
C     ARCON REVISION   25 AUGUST 1970
C
C ***********************************************************************
C
C     THIS PROGRAM READS A TAPE ( IRISET OF DATA WHICH DESCRIBE AN
C     AXIALLY SYMMETRIC STABILIZED CLOUD OF PARTICLES
C     AND TRANSLATES THE HORIZONTAL COORDINATES OF EACH PARCEL
C     TO ACCOUNT FOR WIND DRIFT DURING THE CLOUD RISE TIME INTERVAL.
C     RESULT IS WRITTEN ONTO TAPE JPARIN IN TRANSPORTABLE FORM.
C
C ***************************  GLOSSARY  ********************************
C
C     SEE THE CLOUD RISE - TRANSPORT INTERFACE MODULE GLOSSARY
C
      COMMON /SET1/
     1CAY         ,DETIO(12) ,DIAM(201) ,DMEAN      ,DNS        ,EXPO      ,
     2FMASS(200) ,IDISTR     ,ILAEC     ,IRISE      ,ISIN       ,ISOUT     ,
     3NDSTR       ,PS(200)   ,SD        ,SSAM       ,TME        ,TMP1      ,
     4TMP2        ,T2M       ,USOIL     ,VPR        ,W          ,HEIGHT    ,
     5 SCL        ,RHODO     ,ZV(200)   ,VX(200)    ,VY(200)
C ***********************************************************************
C
      DIMENSION CRID(22),XC(90),YC(90),ATEMP(260),RHO(260),ZC(90),TC(90)
     1,VC(90),IC(18),                      ZPAR(100),XPAR(100),
     1YPAR(100),PSIZ(100),TP(100),PMAS(100),ZT(90),ZB(90),VB(90),VT(90),
     2          RWAF(100),DWAF(100),ZLOW(100),VWAF(100)
C
C ***********************************************************************
C
    1 FORMAT(1X,A6,I3,4E12.5,I5)
    2 FORMAT(///25X,16HCLOUD TRAJECTORY/6X,2HXC,12X,2HYC,12X,2HZC,12X,2H
     1TC,12X,2HVC/5(1X,E13.6))
    4 FORMAT(1X,I5)
 3013 FORMAT( ///
     1          10X,14HBLOCK COUNT = I5// )
 1012 FORMAT(1X,'PARTICLE BLOCK BEFORE SHIFT',/8X,'X',11X,'Y',11X,'T',9X
     1,'PSIZ',9X,'PMAS',10X,'Z',9X,'RWAF',8X,'DWAF',8X,'ZLOW',8X,'VWAF',
     2//(1X,10E12.5))
    3 FORMAT(1X,'PARTICLE BLOCK AFTER SHIFT ',/8X,'X',11X,'Y',11X,'T',9X
     1,'PSIZ',9X,'PMAS',10X,'Z',9X,'RWAF',8X,'DWAF',8X,'ZLOW',8X,'VWAF',
     2//(1X,10E12.5))
C
C ***********************************************************************
C ***********************************************************************
C
      DATA PROGRM/6HWNDSFT/
C
C     INITIALIZE
C
C     COMPUTE CLOUD CENTER  AND STEM DRIFT FACTOR ENTRIES IN RISE TABLE
C
   10 CONTINUE
      DO 25 I=1,NPOSIT
      ZC(I) = (ZB(I)+ZT(I))/2.0
      VC(I)=(VB(I)+VT(I))/2.0
```

```
   25   CONTINUE
        MPOSIT = NPOSIT+1
        MHODO=NHODO-1
C
C       ENSURE THAT WIND VECTORS ARE DEFINED TO ABOVE
C       STABLIZED CLOUD BOTTOM ALTITUDE
C
        IF ((ZV(NHODO)+ZV(MHODO))/2.0 .GE. ZB(NPOSIT)) GO TO 2217
     26 IRROR=-26
        GO TO 7734
C
C       FIND HODOGRAPH VECTOR ALTITUDE APPROPRIATE FOR INITIAL TIME
  2217  J=1
        K=1
   28   IF(ZC(1)-(ZV (J+1)+ZV(J))/2.0)  35,35,30
   30   IF(J-NHODO)   31,32,32
   31   J=J+1
        GO TO 28
   32   IRROR = -32
        GO TO 7734
C
C       COMPUTE HORIZONTAL DISPLACEMENTS VS. TIME FOR THE CLOUD BOTTOM
C       CENTER.
   35   XT=TC(1)*VX(J)
        YT=TC(1)*VY(J)
        XC(1)=XT
        YC(1)=YT
        TTEMP=TC(1)
        ZTEMP=ZC(1)
C
C 122 WHICH IS LOWER, NEXT CLOUD POSIT OR NEXT HODOGRAPH VECTOR
C
   122 IF(J.GE.NHODO) GO TO 124
        IF((ZV(J+1) + ZV(J))/2. -ZC(K+1))123,124,124
   123 DELT=((ZV(J+1)+ ZV(J))/2.- ZTEMP)/VC(K)
        ZTEMP= (ZV(J+1)+ZV(J))/2.
        TTEMP=TTEMP+DELT
        XT=XT+      VX(J)*DELT
        YT=YT+      VY(J)*DELT
        J=J+1
        GO TO 122
C
C       NEXT CLOUD CELL CENTER IS LOWER
   124 DELT=TC(K+1)-TTEMP
        TTEMP=TC(K+1)
        ZTEMP=ZC(K+1)
        XC(K+1)=XT+VX(J)*DELT
        YC(K+1)=YT+VY(J)*DELT
        XT=XC(K+1)
        YT=YC(K+1)
        K=K+1
        IF(K-NPOSIT)122,125,125
C
C 125 CLOUD TRAJECTORY IS COMPLETE
  125   WRITE (ISOUT,2)(XC(J),YC(J),ZC(J),TC(J),VC(J),J=1,NPOSIT)
C
   104 READ(IRISE)N
```

```
      IF(N)102,102,103
C
C 102 FINAL EXIT.   ALL DATA HAVE BEEN MODIFIED.  MARK JPARIN COMPLETED.
 102  N=0
      IF(IC(3))2013,2014,2013
 2013 WRITE(ISOUT,3013)N
 2014 WRITE(JPARIN)N
      END FILE JPARIN
      REWIND JPARIN
      REWIND IRISE
      RETURN
 7734 CALL ERROR(PROGRM,IRROR,ISOUT)
      RETURN
C
C 103 READ A BLOCK OF N PARTICLE DESCRIPTIONS
  103 READ(IRISE )(XPAR(J),YPAR(J),TP(J),PSIZ(J),PMAS(J),ZPAR(J),RWAF(J)
     1,DWAF(J),ZLOW(J),VWAF(J),J=1,N)
      IF(IC(3))2015,2010,2015
 2015 WRITE(ISOUT,3013)N
      WRITE(ISOUT,1012)(XPAR(I),YPAR(I),TP(I),PSIZ(I),PMAS(I),ZPAR(I),
     1RWAF(I),DWAF(I),ZLOW(I),VWAF(I),I=1,N)
C
C     NOW PREPARE TO SHIFT PARTICLES HORIZONTALLY IN ACCORDANCE WITH THE
C     POSITION OF THE CLOUD AT THE TIME WHEN THE PARTICLE LEFT THE CLOUD
C
C          FIRST INITIALIZE FOR ENTERING A LOOP ON PARTICLES
 2010 OLDZ=-99999.0
      OLDPS=-1.0
      OLDT=-1.0
      J=1
C 105 WAS THE CURRENT (J-TH) PARTICLE DEFINED AT THE SAME TIME AS THE
C     PREVIOUS ONE.   YES TO 1051
  105 IF(TP(J)-OLDT)106,1051,106
C
C1051 IS THE CURRENT (J-TH) PARTICLE THE SAME SIZE AS THE PREVIOUS ONE.
C     YES TO 107
 1051 IF(PSIZ(J)-OLDPS)106,107,106
C
C 107 IS THE J-TH PARTICLE AT THE SAME ALTITUDE AS THE PREVIOUS ONE.
C     YES TO 108
 107  IF(ZPAR(J)-OLDZ)106,108,106
C
C 108 THE PARTICLE WILL HAVE THE SAME HORIZONTAL DISPLACEMENTS AS THE
C     PREVIOUS ONE AND WILL LEAVE THE CLOUD AT THE SAME TIME AND ALTI-
C     TUDE AS THE PREVIOUS ONE. ADDITION OF XGZ,YGZ MAKES XPAR, YPAR
C     RELATIVE TO COORDINATE SYSTEM ORIGIN
  108 TP(J)=TP(J)+TGZ
 109  XPAR(J)=XPAR(J)+DX+XGZ
      YPAR(J)=YPAR(J)+DY+YGZ
C
C     INCREMENT AND TEST J TO CONSIDER THE NEXT PARTICLE OR RETURN TO
C     FETCH THE NEXT BLOCK OF PARTICLE DATA.
      J=J+1
      IF(J-N)105,105,110
C
C 110 PUT THE MODIFIED DATA ON THE TAPE JPARIN AND THEN RETURN TO
C     FETCH THE NEXT DATA BLOCK.
```

```
  110 WRITE(JPART)N                                                      WNSFT172
      WRITE (JPART)(XPAR(J),YPAR(J),ZPAR(J),TP(J),PSIZ(J),PMAS(J),RWAF  WNSFT173
     1(J),DWAF(J),ZLOW(J),VWAF(J),J=1,N)                                WNSFT174
      IF(IC(3))185,104,185                                              WNSFT175
  185 WRITE (ISOUT,4)N                                                   WNSFT176
      WRITE(ISOUT,3)(XPAR(I),YPAR(I),TP(I),PSIZ(I),PMAS(I),ZPAR(I),     WNSFT177
     1RWAF(I),DWAF(I),ZLOW(I),VWAF(I),I=1,N)                            WNSFT178
  190 GO TO 104                                                          WNSFT179
 106  OLDPS=PSIZ(J)                                                      WNSFT180
      OLDZ=ZPAR(J)                                                       WNSFT181
      OLDT=TP(J)                                                         WNSFT182
C                                                                        WNSFT183
C     DID J-TH PARTICLE LEAVE THE CLOUD.    NO TO 115                    WNSFT184
      IF(ZPAR(J)-ZB(NPOSIT))114,115,115                                  WNSFT185
C                                                                        WNSFT186
C 115 TAKE CARE OF PARTICLES THAT DONT L.AVE THE CLOUD                   WNSFT187
 115  DX=XC(NPOSIT)                                                      WNSFT188
      DY=YC(NPOSIT)                                                      WNSFT189
C     TP(J) AND ZPAR(J) ARE OK AS IS.                                    WNSFT190
      GO TO 108                                                          WNSFT191
C                                                                        WNSFT192
C 114 THE PARTICLE HAS LEFT THE CLOUD                                    WNSFT193
C                                                                        WNSFT194
  114 ZCUR=ZPAR(J)                                                       WNSFT195
      TCUR=TP(J)                                                         WNSFT196
      DX=0.                                                              WNSFT197
      DY=0.                                                              WNSFT198
C                                                                        WNSFT199
C     LOCATE PARTICLE DEFINITION TIME IN THE CLOUD RISE TABLE.           WNSFT200
C                                                                        WNSFT201
      DO 210 K=1,NPOSIT                                                  WNSFT202
      LL=MPOSIT-K                                                        WNSFT203
      IF(TC(LL).LE.TP(J)) GO TO 221                                      WNSFT204
  210 CONTINUE                                                           WNSFT205
  211 IRROR=-211                                                         WNSFT206
      GO TO 7734                                                         WNSFT207
C                                                                        WNSFT208
C 221 LOCATE INITIAL PARTICLE ALTITUDE IN THE WIND HODOGRAPH TABLE       WNSFT209
C                                                                        WNSFT210
  221 DO 230 K 1,MHODO                                                   WNSFT211
      IF((ZV(K)+ZV(K+1))/2.0.GT.ZPAR(J))GO TO 240                        WNSFT212
  230 CONTINUE                                                           WNSFT213
      MM=NHODO                                                           WNSFT214
      GO TO 220                                                          WNSFT215
  240 MM=K                                                               WNSFT216
C                                                                        WNSFT217
C 220 FIND CLOUD BOTTOM ALTITUDE AT THE PARTICLE DEFINITION TIME         WNSFT218
  220 ZBOTOM= ZB(LL) +(TP(J)-TC(LL))*VB(LL)                              WNSFT219
      IF((ZBOTOM- ZCUR).LE.115.*W**(0.151)) GO TO 225                    WNSFT220
C                                                                        WNSFT221
C     LOCATE INITIAL PARTICLE ALTITUDE IN THE CLOUD RISE HISTORY TABLE   WNSFT222
C                                                                        WNSFT223
      DO 222 K=1,NPOSIT                                                  WNSFT224
      NN=MPOSIT-K                                                        WNSFT225
      IF(ZB(NN).LE.ZCUR) GO TO 224                                       WNSFT226
  222 CONTINUE                                                           WNSFT227
C                                                                        WNSFT228
```

```
C     COMPUTE AN AVERAGE BASE RATE, BV
C
  224 IF(LL.GT.NN)GO TO 3224
      BV=VB(LL)
      GO TO 3227
 3224 BV=0.
      DO 3225 K=NN,LL
      IF(K.EQ.NPOSIT ) GO TO 3226
 3225 BV=BV +VB(K)*(TC(K+1)- TC(K))
 3226 BV= BV/(TC(LL)-TC(NN))
 3227 SIZ=PSIZ(J)*1.0E6
      CALL FALRAT(ZCUR,SIZ,FV,ATEMP,RHO,FROG,ISOUT)
C
C     CAN THE PARTICLE BE MOVED SIGNIFICANTLY IN THE TIME AVAILABLE----
C             YES TO 250
C             NO TO 315
C
      IF(( ZBOTOM-ZCUR+10.0).LT.(TP(J)-TC(1))*(FV+BV)) GO TO 250
  225 DELTEE=0.
      GO TO 315
C
C    INDEX  MM IDENTIFIES THE WIND HODOGRAPH STRATUM IN WHICH THE
C     PARTICLE IS CURRENTLY DEFINED.
C
C     INDEX LL   IDENTIFIES THE CLOUD RISE HISTORY TABLE ENTRY WHICH
C     REPRESENTS THE RISE INCREMENT DURNING WHICH THE PARTICLE IS
C     CURRENTLY DEFINED.
C
C 245 LOCATE CURRENT PARTICLE ALTITUDE IN THE WIND HODOGRAPH TABLE
C
  245 DO 246 K=1,NHODO
      IF((ZV(K) +ZV(K+1))/2.0 .GT. (ZCUR+ 1.0))GO TO 247
  246 CONTINUE
      MM=NHODO
      GO TO 250
  247 MM=K
C
  250 CONTINUE
C
C     DETERMINE IF NET PARTICLE MOTION IS UPWARD OR DOWNWARD.
C                   UPWARD TO 251
      SIZ=PSIZ(J)*1.0E6
      CALL FALRAT(ZCUR,SIZ,FV,ATEMP,RHO,FROG,ISOUT)
C
C                   DOWNWARD TO 253
C
      IF((ZBOTOM-ZBRSTZ) .GT.0.0) GO TO 2298
 2297 RV=0.
      GO TO 2299
 2298 RV=VB(LL)*( 1.0+( ZCUR-ZBOTOM)/( ZBOTOM-ZBRSTZ))
      IF(RV.LT.0.0) GO TO 2297
      IF(RV.GT.(VB(LL)+.001)) RV=VB(LL)
 2299 IF(FV-RV .GE.0.0)GO TO 253
C
C 251 COMPUTE THE TIMES REQUIRED FOR THE PARTICLE TO MOVE TO THE
C     BOTTOM OF THE HODOGRAPH STRATUM IN WHICH IT RESIDES,AND TO THE
C     BASE OF THE CLOUD.  USE THE SMALLER OF THESE TIMES.
```

```
C
  251 IF((MM-1).GT.0) GO TO 252
      DELZEE= ZBRSTZ-ZCUR
      GO TO 1253
  252 DELZEE= (ZV(MM) +ZV(MM-1))/ 2.0-ZCUR
      IF(DELZEE .LT. -0.01)GO TO 1253
      MM=MM-1
      GO TO 251
 1253 DELTEP= DELZEE/(FV-RV)
  254 DELTEE=(ZBOTOM-ZCUR)/(FV-RV+VB(LL))
      IF( DELTEE.LT. DELTEP) GO TO 255
      DELTEE= DELTEP
  255 IF(DELTEE.GE.0.0) GO TO 278
  256 IRROR=-256
      GO TO 7734
C
C 253 COMPUTE THE TIMES REQUIRED FOR THE PARTICLE TO MOVE TO THE TOP OF
C     THE HODOGRAPH STRATUM IN WHICH IT RESIDES.AND TO THE BASE OF THE
C     CLOUD.  USE THE SMALLER OF THESE TIMES.
C
  253 DELTEP= ((ZV(MM)+ ZV(MM+1))/2.0 -ZCUR)/(FV-RV)
      GO TO 254
C
  278 TMIUDT=TCUR-DELTEE
      IF(IC(4).EQ.0)GO TO 279
      IAC=278
      WRITE(ISOUT,2310)IAC,
     1                J,LL,MM,LLL,DELTEE,ZBOTOM,RV,FV,TCUR,ZCUR,TMIUDT
 2310 FORMAT(I5/
     1           4I5/7(3X,E12.5))
C
C     FIND THE POSITION OF TIME TMIUDT IN THE CLOUD RISE TABLE.
C
  279 LLL=LL
  280 IF(TC(LL).LE.TMIUDT) GO TO 290
      LL=LL-1
      IF(LL.GE.1) GO TO 280
      TMIUDT= TC(1)
      LL=1
      DELTEE=TCUR-TC(1)
C
C     COMPUTE THE CLOUD BOTTOM HEIGHT,ZBOTOM,AT THE TIME TMIUDT.
C
  290 ZBOTOM=ZB(LL)+VB(LL)*(TMIUDT-TC(LL))
C
C     IS THIS CLOUD BOTTOM ALTITUDE LESS THAN OR EQUAL TO THE PARTICLE
C     ALTITUDE-
C        YES TO 295 OR 320
C        NO  TO 300
C
  291 TMPDZ=ZBOTOM-ZCUR-(FV-RV)*DELTEE
      IF(ABS(TMPDZ).LE.5.0) GO TO 320
      IF(TMPDZ)295,320,300
C

C 295 CLOUD BASE AND PARTICLE TRAJECTORIES HAVE CROSSED.  IF POSSIBLE,
C     GO BACK TO THE STEP JUST BEFORE THE CROSSING OCCURS.
```

```
C
  295 LL=LL+1
      IF(LLL-LL)296,310,297
  296 LL=LLL
      GO TO 310
  297 DELTEE= TCUR-TC(LL)
      ZBOTOM=ZB(LL)
      TMPDZ=ZBOTOM-ZCUR-(FV-RV)*DELTEE
      IF(ABS(TMPDZ).LE.5.0) GO TO 311
      IF(TMPDZ)295,311,300
C
C 300 INCREMENT PARTICLE SHIFT PARAMETERS
  300 DX=DX+VX( MM) *DELTEE
      DY=DY+VY( MM) *DELTEE
      TCUR=TCUR-DELTEE
      ZCUR=ZCUR+(FV-RV)*DELTEE
      IF(IC(4).EQ.0)GO TO 245
      IAC=300
      WRITE(ISOUT,2310)IAC,
     1                  J,LL,MM,LLL,DELTEE,ZBOTOM,RV,FV,TCUR,ZCUR,TMIUDT
      GO TO 245
C
C
C 310 MAKE FINAL ADJUSTMENTS TO PARTICLE SHIFT PARAMETERS.
C
C
  310 ZBOTOM=ZB( LL)+VB( LL)*(TCUR-TC( LL))
      DELTEE=(ZBOTOM-ZCUR)/(VB( LL)-RV+FV)
  311 IF(DELTEE.LT. 0.0)DELTEE=0.
      IF((TCUR-DELTEE).LT. 0.0) DELTEE=0.0
  315 IF(TC(LL) .LE. (TCUR-DELTEE-0.1)) GO TO 320
      LL=LL-1
      IF(LL.GE.1) GO TO 315
      LL=1
  320 DELTRP =(TCUR -DELTEE-TC( LL))/(TC( LL+1) -TC( LL))
  322 DX=DX+VX( MM)*DELTEE + XC( LL)  + (XC( LL+1) -XC( LL))*DELTRP
      DY=DY+VY( MM)*DELTEE + YC( LL)  + (YC( LL+1) -YC( LL))*DELTRP
      IF(IC(4).EQ.0)GO TO 108
      IAC=320
      WRITE(ISOUT,2310)IAC,
     1                  J,LL,MM,LLL,DELTEE,ZBOTOM,RV,FV,TCUR,ZCUR,TMIUDT
      GO TO 108
C
      END
```

```
      SUBROUTINE  FALRAT(ALT.PSIZE.FV.ATEMP.RHO.FROG.ISOUT)
C
C***********************************************************************
C
C     SUBROUTINE FALRAT.USING DAVIE'S EQUATIONS. COMPUTES THE SETTLING
C     RATE OF PARTICLES.
C
C***********************************************************************
C
C
C**********************    FALRAT GLOSSARY    ****************************
C
C     ATEMP          DYNAMIC VISCOSITY OF AIR
C                                     (KILOGRAM/METER-SECOND)
C     CDRR           THE DRAG COEFFICIENT * SQUARE OF THE REYNOLD-S
C                    NUMBER.
C     FROG           (4/3)*PARTICLE DENSITY*GRAVITY*(CUBIC METERS/ CUBIC
C                    MICRON).  KILOGRAM-METER/((SQR. SEC.)*(CUBIC MICRON))
C     FV             SETTLING RATE     (METERS/SEC)
C     PSIZE          PARTICLE DIAMETER     (MICRONS)
C     RHO            ATM DENSITY                                  (KILO-
0                    GRAMS/ CUBIC METER)
C
C***********************************************************************
C
      DIMENSION ATEMP(260).RHO(260)
 2    FORMAT(//38H DAVIES EQUATIONS ARE INACCURATE FOR  .F12.3.12H MICRO
     1NS AT .F12.3.7H METERS)
      I=(ALT/200.0)+6.5
      VO=PSIZE/ATEMP(I)
      V1=PSIZE*VO*FROG
      CDRR=V1*RHO(I)*VO
      IF(CDRR-140.0)100.100.149
 149  IF(ISOUT.LT.0)GO TO 200
 150  IF (CDRR-4.5E+7)200.151.151
 151  WRITE (ISOUT.2)PSIZE.ALT
      GO TO 200
 100  FV=V1*(41666.7 +CDRR*(-2.3353E+2+CDRR*(2.0154   -6.9105E-3*CDRR)))
      GO TO 300
 200  QLOGA=ALOG10(CDRR)-20.773
      FV=50657.0 *V1*CDRR**((QLOGA*QLOGA-443.98)*0.0011235)
 300  FV=FV*(1.0+2.33E-1/(PSIZE*RHO(I)))
 301  RETURN
      END
```

SAMPLE PROBLEM AND PRINTOUT

On pp. 194 through 202 is presented a printout of a CRTIM calculation suitable for debugging usage. For this printout the complete parcel data output was requested (IC(3) = 1). Only the beginning of this latter printout is displayed here. A block of parcel data taken directly from the input storage unit, IRISE, that has not been corrected for wind drift is printed first. Next the same block of data corrected for wind-drift is printed. Then, the next block of uncorrected data, etc.

THE DEPARTMENT OF DEFENSE FALLOUT PREDICTION SYSTEM

CLOUD RISE - TRANSPORT INTERFACE MODULE

PREPARED BY
ARCON CORPORATION
WAKEFIELD, MASS.

FW	SSAM	SLDTMP	THST	SIGMA
0.150000E 05	0.436531E 16	0.280000E 04	0.153830E 02	0.216000E 01

TW	HOB	HZ	RDPART
0.150000E 05	0.0	0.0	0.250000E 04

PSEID
BRAVO 15 MT 15 OCTOBER 1970 IBM 360/75

CRID
BRAVO 15 MT 15 OCTOBER 1970 IBM 360/75

TPRID
BRAVO 15 MT 15 OCTOBER 1970 IBM 360/75

CONTROL ARRAY IC(J),J=1,18
0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

DETONATION COORDINATES	XGZ	YGZ	TGZ
	0.0	0.0	0.0

NOSTR = 50

PARTICLE SIZE (MICROMETERS)	MASS FRACTION	SIZE CLASS UPPER BOUND (MICROMETERS)
0.807093E 03	0.200000E-01	0.995523E 03
0.582109E 03	0.200000E-01	0.654263E 03
0.480399E 03	0.200000E-01	0.514055E 03
0.420516E 03	0.200000E-01	0.443431E 03
0.379502E 03	0.200000E-01	0.395351E 03
0.346392E 03	0.200000E-01	0.360912E 03
0.320547E 03	0.200000E-01	0.332457E 03
0.299005E 03	0.200000E-01	0.303064E 03
0.280589E 03	0.200000E-01	0.289274E 03

0.2646[illegible]E 03	0.200000E-01	0.2721575E 03
0.25[illegible]329[illegible]E 03	0.200000E-01	0.2571238E 03
0.237420[illegible]E 03	0.200000E-01	0.243731[illegible]E 03
0.2261055E 03	0.200000E-01	0.2316632E 03
0.215[illegible]E 03	0.200000E-01	0.2205[illegible]E 03
0.2055[illegible]E 03	0.200000E-01	0.2105[illegible]E 03
0.1970115E 03	0.200000E-01	0.2013[illegible]E 03
0.1885597E 03	0.200000E-01	0.1927[illegible]E 03
0.18[illegible]E 03	0.200000E-01	0.1847[illegible]E 03
0.1738621E 03	0.200000E-01	0.1771[illegible]E 03
0.1667[illegible]E 03	0.200000E-01	0.1701115E 03
0.1602[illegible]E 03	0.200000E-01	0.1634[illegible]E 03
0.154033[illegible]E 03	0.200000E-01	0.15703[illegible]E 03
0.14[illegible]13[illegible]E 03	0.200000E-01	0.1510[illegible]E 03
0.1425[illegible]E 03	0.200000E-01	0.1452[illegible]E 03
0.1371155E 03	0.200000E-01	0.13[illegible]7822E 03
0.1319[illegible]E 03	0.200000E-01	0.134[illegible]E 03
0.1269[illegible]E 03	0.200000E-01	0.129[illegible]17E 03
0.12211[illegible]E 03	0.200000E-01	0.12[illegible]512E 03
0.1174[illegible]E 03	0.200000E-01	0.11[illegible]7[illegible]7E 03
0.112[illegible]E 03	0.200000E-01	0.1151[illegible]E 03
0.108[illegible]E 03	0.200000E-01	0.111[illegible]E 03
0.104193[illegible]E 03	0.200000E-01	0.1063[illegible]E 03
0.99[illegible]8[illegible]E 02	0.200000E-01	0.1[illegible]2[illegible]E 03
0.955[illegible]01[illegible]E 02	0.200000E-01	0.97[illegible]E 02
0.91623[illegible]E 02	0.200000E-01	0.[illegible]3[illegible]E 02
0.8753[illegible]E 02	0.200000E-01	0.[illegible]E 02
0.83[illegible]045[illegible]E 02	0.200000E-01	0.[illegible]E 02
0.80[illegible]E 02	0.200000E-01	0.81[illegible]E 02
0.761[illegible]E 02	0.200000E-01	0.78[illegible]E 02
0.722[illegible]E 02	0.200000E-01	0.74222[illegible]E 02
0.683[illegible]E 02	0.200000E-01	0.70[illegible]E 02
0.6447[illegible]E 02	0.200000E-01	0.66[illegible]E 02
0.6050[illegible]E 02	0.200000E-01	0.625[illegible]E 02
0.5643[illegible]E 02	0.200000E-01	0.5[illegible]E 02
0.5222[illegible]E 02	0.200000E-01	0.5441[illegible]E 02
0.477[illegible]E 02	0.200000E-01	0.501237[illegible]E 02
0.430190[illegible]E 02	0.200000E-01	0.45[illegible]E 02
0.374566[illegible]E 02	0.200000E-01	0.40[illegible]E 02
0.310727[illegible]E 02	0.200000E-01	0.349[illegible]E 02
0.224146[illegible]E 02	0.200000E-01	0.27[illegible]E 02

KDPST = 4

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[illegible]	0.130130E-04	0.127230E 01
[illegible]	0.179570E-04	0.124370E 01
[illegible]	0.134440E-04	0.115970E 01
[illegible]	0.133500E-04	0.115210E 01
[illegible]	0.132570E-04	0.113450E 01
[illegible]	0.131790E-04	0.111710E 01
[illegible]	0.131050E-04	0.109700E 01
[illegible]	0.130530E-04	0.107570E 01
[illegible]	0.179510E-04	0.105650E 01
[illegible]	0.179170E-04	0.103540E 01
[illegible]	0.173760E-04	0.101420E 01
[illegible]	0.173350E-04	0.993050E 00
[illegible]	0.173270E-04	0.970000E 00
[illegible]	0.173260E-04	0.943730E 00
[illegible]	0.175240E-04	0.925570E 00
[illegible]	0.177650E-04	0.903510E 00
[illegible]	0.175710E-04	0.891650E 00
[illegible]	0.174130E-04	0.874720E 00
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[illegible]	0.174370E-04	0.840270E 00
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[illegible]	0.170840E-04	0.725330E 00
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[illegible]	0.158190E-04	0.657830E 00
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[illegible]	0.164170E-04	0.620030E 00
[illegible]	0.165500E-04	0.607350E 00
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[illegible]	0.159510E-04	0.513730E 00
[illegible]	0.158620E-04	0.503730E 00
[illegible]	0.157740E-04	0.493730E 00
[illegible]	0.156860E-04	0.483730E 00
[illegible]	0.155970E-04	0.473730E 00
[illegible]	0.155100E-04	0.463340E 00
[illegible]	0.154230E-04	0.454570E 00
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[illegible]	0.152510E-04	0.435130E 00
[illegible]	0.151640E-04	0.425350E 00
[illegible]	0.150780E-04	0.417590E 00
[illegible]	0.149920E-04	0.404310E 00
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0.112000E 05	0.146390E-04	0.37464E 00
0.114000E 05	0.145500E-04	0.36665E 00
0.116000E 05	0.144510E-04	0.35855E 00
0.118000E 05	0.143720E-04	0.35057E 00
0.120000E 05	0.142820E-04	0.34263E 00
0.122000E 05	0.141940E-04	0.33474E 00
0.124000E 05	0.141130E-04	0.32775E 00
0.126000E 05	0.140320E-04	0.32073E 00
0.128000E 05	0.139510E-04	0.31333E 00
0.130000E 05	0.138700E-04	0.30532E 00
0.132000E 05	0.137890E-04	0.29734E 00
0.134000E 05	0.137030E-04	0.29236E 00
0.136000E 05	0.136270E-04	0.28533E 00
0.138000E 05	0.135520E-04	0.27721E 00
0.140000E 05	0.134650E-04	0.27237E 00
0.142000E 05	0.134190E-04	0.26573E 00
0.144000E 05	0.133530E-04	0.26043E 00
0.146000E 05	0.132870E-04	0.25424E 00
0.148000E 05	0.132200E-04	0.24300E 00
0.150000E 05	0.131540E-04	0.24175E 00
0.152000E 05	0.130880E-04	0.23352E 00
0.154000E 05	0.130520E-04	0.22342E 00
0.156000E 05	0.130240E-04	0.22337E 00
0.158000E 05	0.129960E-04	0.21731E 00
0.160000E 05	0.129630E-04	0.21125E 00
0.162000E 05	0.129400E-04	0.20520E 00
0.164000E 05	0.129130E-04	0.19914E 00
0.166000E 05	0.128950E-04	0.19309E 00
0.168000E 05	0.130140E-04	0.17350E 00
0.170000E 05	0.128890E-04	0.16757E 00
0.172000E 05	0.130340E-04	0.16170E 00
0.174000E 05	0.130400E-04	0.15534E 00
0.176000E 05	0.131250E-04	0.14937E 00
0.178000E 05	0.131710E-04	0.14411E 00
0.180000E 05	0.132160E-04	0.13324E 00
0.182000E 05	0.132610E-04	0.13349E 00
0.184000E 05	0.133060E-04	0.12374E 00
0.186000E 05	0.133510E-04	0.12337E 00
0.188000E 05	0.133960E-04	0.11923E 00
0.190000E 05	0.134410E-04	0.11443E 00
0.192000E 05	0.134860E-04	0.11052E 00
0.194000E 05	0.135310E-04	0.10675E 00
0.196000E 05	0.135750E-04	0.10233E 00
0.198000E 05	0.136200E-04	0.99019E-01
0.200000E 05	0.136650E-04	0.95154E-01
0.202000E 05	0.137090E-04	0.91999E-01
0.204000E 05	0.137530E-04	0.88345E-01
0.206000E 05	0.137970E-04	0.85591E-01
0.208000E 05	0.138420E-04	0.82536E-01
0.210000E 05	0.138860E-04	0.79331E-01
0.212000E 05	0.139300E-04	0.75773E-01
0.214000E 05	0.139740E-04	0.74200E-01
0.216000E 05	0.140180E-04	0.71622E-01
0.218000E 05	0.140620E-04	0.69035E-01
0.220000E 05	0.141060E-04	0.66443E-01
0.222000E 05	0.141320E-04	0.64395E-01
0.224000E 05	0.141590E-04	0.62343E-01
0.226000E 05	0.141850E-04	0.60299E-01
0.228000E 05	0.142120E-04	0.58233E-01
0.230000E 05	0.142380E-04	0.56135E-01
0.232000E 05	0.142620E-04	0.54474E-01
0.234000E 05	0.142860E-04	0.52763E-01

0.236000E 05	0.143100E-04	0.510520E-01
0.238000E 05	0.143340E-04	0.493410E-01
0.240000E 05	0.143580E-04	0.476300E-01
0.242000E 05	0.143810E-04	0.461340E-01
0.244000E 05	0.144050E-04	0.447530E-01
0.246000E 05	0.144290E-04	0.433220E-01
0.248000E 05	0.144530E-04	0.419350E-01
0.250000E 05	0.144760E-04	0.404490E-01
0.252000E 05	0.145000E-04	0.392420E-01
0.254000E 05	0.145240E-04	0.380350E-01
0.256000E 05	0.145470E-04	0.368270E-01
0.258000E 05	0.145710E-04	0.356200E-01
0.260000E 05	0.145950E-04	0.344120E-01
0.262000E 05	0.146180E-04	0.333930E-01
0.264000E 05	0.146420E-04	0.323740E-01
0.266000E 05	0.146650E-04	0.313550E-01
0.268000E 05	0.146890E-04	0.303350E-01
0.270000E 05	0.147120E-04	0.293170E-01
0.272000E 05	0.147360E-04	0.284530E-01
0.274000E 05	0.147590E-04	0.275930E-01
0.276000E 05	0.147830E-04	0.267390E-01
0.278000E 05	0.148060E-04	0.258730E-01
0.280000E 05	0.148300E-04	0.250190E-01
0.282000E 05	0.148530E-04	0.242920E-01
0.284000E 05	0.148760E-04	0.235650E-01
0.286000E 05	0.149000E-04	0.228330E-01
0.288000E 05	0.149230E-04	0.221110E-01
0.290000E 05	0.149460E-04	0.213930E-01
0.292000E 05	0.149700E-04	0.207580E-01
0.294000E 05	0.149930E-04	0.201520E-01
0.296000E 05	0.150160E-04	0.195370E-01
0.298000E 05	0.150390E-04	0.189210E-01
0.300000E 05	0.150620E-04	0.183060E-01
0.302000E 05	0.150860E-04	0.177340E-01
0.304000E 05	0.151090E-04	0.172510E-01
0.306000E 05	0.151320E-04	0.167390E-01
0.308000E 05	0.151550E-04	0.162160E-01
0.310000E 05	0.151780E-04	0.156940E-01
0.312000E 05	0.152010E-04	0.152500E-01
0.314000E 05	0.152240E-04	0.148060E-01
0.316000E 05	0.152470E-04	0.143520E-01
0.318000E 05	0.152700E-04	0.139130E-01
0.320000E 05	0.152930E-04	0.134740E-01
0.322000E 05	0.153160E-04	0.130950E-01
0.324000E 05	0.153390E-04	0.127180E-01
0.326000E 05	0.153620E-04	0.123400E-01
0.328000E 05	0.153850E-04	0.119520E-01
0.330000E 05	0.154080E-04	0.115840E-01
0.332000E 05	0.154310E-04	0.112620E-01
0.334000E 05	0.154540E-04	0.109340E-01
0.336000E 05	0.154760E-04	0.106130E-01
0.338000E 05	0.154990E-04	0.102960E-01
0.340000E 05	0.155220E-04	0.997420E-02
0.342000E 05	0.155450E-04	0.969340E-02
0.344000E 05	0.155670E-04	0.942450E-02
0.346000E 05	0.155900E-04	0.914950E-02
0.348000E 05	0.156130E-04	0.887470E-02
0.350000E 05	0.156360E-04	0.859930E-02
0.352000E 05	0.156580E-04	0.835490E-02
0.354000E 05	0.156810E-04	0.813010E-02
0.356000E 05	0.157040E-04	0.799330E-02
0.358000E 05	0.157260E-04	0.765040E-02
0.360000E 05	0.157490E-04	0.742550E-02

0.362000E 05	0.157710E-04	0.722430E-02
0.364000E 05	0.157940E-04	0.702300E-02
0.366000E 05	0.158160E-04	0.682170E-02
0.368000E 05	0.158390E-04	0.662040E-02
0.370000E 05	0.158620E-04	0.641910E-02
0.372000E 05	0.158840E-04	0.624660E-02
0.374000E 05	0.159060E-04	0.607420E-02
0.376000E 05	0.159290E-04	0.590180E-02
0.378000E 05	0.159510E-04	0.572930E-02
0.380000E 05	0.159740E-04	0.555690E-02
0.382000E 05	0.159960E-04	0.540370E-02
0.384000E 05	0.160180E-04	0.525100E-02
0.386000E 05	0.160410E-04	0.511310E-02
0.388000E 05	0.160630E-04	0.496510E-02
0.390000E 05	0.160850E-04	0.481720E-02
0.392000E 05	0.161080E-04	0.469000E-02
0.394000E 05	0.161300E-04	0.455270E-02
0.396000E 05	0.161520E-04	0.443550E-02
0.398000E 05	0.161740E-04	0.430330E-02
0.400000E 05	0.161960E-04	0.418110E-02
0.402000E 05	0.162190E-04	0.407140E-02
0.404000E 05	0.162410E-04	0.395130E-02
0.406000E 05	0.162630E-04	0.385210E-02
0.408000E 05	0.162850E-04	0.374240E-02
0.410000E 05	0.163070E-04	0.363230E-02
0.412000E 05	0.163290E-04	0.353840E-02
0.414000E 05	0.163510E-04	0.344410E-02
0.416000E 05	0.163730E-04	0.334930E-02
0.418000E 05	0.163950E-04	0.325540E-02
0.420000E 05	0.164180E-04	0.316110E-02
0.422000E 05	0.164390E-04	0.307950E-02
0.424000E 05	0.164610E-04	0.299800E-02
0.426000E 05	0.164830E-04	0.291650E-02
0.428000E 05	0.165050E-04	0.283490E-02
0.430000E 05	0.165270E-04	0.275340E-02
0.432000E 05	0.165490E-04	0.268300E-02
0.434000E 05	0.165710E-04	0.261260E-02
0.436000E 05	0.165930E-04	0.254220E-02
0.438000E 05	0.166150E-04	0.247130E-02
0.440000E 05	0.166370E-04	0.240140E-02
0.442000E 05	0.166590E-04	0.234040E-02
0.444000E 05	0.166800E-04	0.227950E-02
0.446000E 05	0.167020E-04	0.221850E-02
0.448000E 05	0.167240E-04	0.215750E-02
0.450000E 05	0.167460E-04	0.209570E-02
0.452000E 05	0.167670E-04	0.204400E-02
0.454000E 05	0.167890E-04	0.199120E-02
0.456000E 05	0.168110E-04	0.193850E-02
0.458000E 05	0.168320E-04	0.188570E-02
0.460000E 05	0.168540E-04	0.183300E-02
0.462000E 05	0.168760E-04	0.178720E-02
0.464000E 05	0.168970E-04	0.174150E-02
0.466000E 05	0.169190E-04	0.169570E-02
0.468000E 05	0.169400E-04	0.164990E-02
0.470000E 05	0.169620E-04	0.160420E-02
0.472000E 05	0.169720E-04	0.156350E-02
0.474000E 05	0.169820E-04	0.152700E-02
0.476000E 05	0.169920E-04	0.148940E-02
0.478000E 05	0.170020E-04	0.144930E-02
0.480000E 05	0.170120E-04	0.141120E-02
0.482000E 05	0.170120E-04	0.137320E-02
0.484000E 05	0.170120E-04	0.134530E-02
0.486000E 05	0.170120E-04	0.131230E-02

0.488000E 05	0.170120E-04	0.127930E-02
0.490000E 05	0.170120E-04	0.124530E-02
0.492000E 05	0.170120E-04	0.121720E-02
0.494000E 05	0.170120E-04	0.118310E-02
0.496000E 05	0.170120E-04	0.115990E-02
0.498000E 05	0.170120E-04	0.112780E-02
0.500000E 05	0.170120E-04	0.110070E-02

NPOSIT= 39

TC(J)	ZB(J)	ZT(J)	VE(J)	VT(J)
0.128780E 02	0.116756E 04	0.502515E 04	0.122055E 03	0.237583E 03
0.130655E 02	0.119066E 04	0.506970E 04	0.127226E 03	0.247589E 03
0.135030E 02	0.124652E 04	0.517802E 04	0.137943E 03	0.253446E 03
0.143780E 02	0.136722E 04	0.541291E 04	0.156652E 03	0.304657E 03
0.158780E 02	0.160220E 04	0.587013E 04	0.175837E 03	0.342307E 03
0.173779E 02	0.186604E 04	0.638365E 04	0.175052E 03	0.340666E 03
0.198779E 02	0.230368E 04	0.723532E 04	0.166054E 03	0.313115E 03
0.228779E 02	0.276635E 04	0.817466E 04	0.147580E 03	0.297201E 03
0.263779E 02	0.330285E 04	0.917386E 04	0.136666E 03	0.265544E 03
0.308779E 02	0.391524E 04	0.103793E 05	0.129404E 03	0.251829E 03
0.363779E 02	0.462056E 04	0.117644E 05	0.125302E 03	0.243845E 03
0.428779E 02	0.544542E 04	0.133494E 05	0.124165E 03	0.241641E 03
0.508779E 02	0.643577E 04	0.152825E 05	0.125266E 03	0.243780E 03
0.593779E 02	0.756355E 04	0.173546E 05	0.128680E 03	0.250419E 03
0.693779E 02	0.879035E 04	0.198588E 05	0.133655E 03	0.250179E 03
0.808779E 02	0.103278E 05	0.228509E 05	0.135770E 03	0.264217E 03
0.938779E 02	0.120923E 05	0.262857E 05	0.122517E 03	0.233426E 03
[illegible]	0.138693E 05	0.297423E 05	0.874790E 02	0.170240E 03
[illegible]	0.155752E 05	0.330625E 05	0.389766E 02	0.758552E 02
[illegible]	0.161599E 05	0.342004E 05	0.286600E 01	0.445234E 01
[illegible]	0.162171E 05	0.342894E 05	0.0	0.0
[illegible]	0.162171E 05	0.342894E 05	0.0	0.0
[illegible]	0.162171E 05	0.342894E 05	0.0	0.0
0.232378E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.262678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.292978E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.322878E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.357678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.392678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.432678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.477375E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.522678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.567678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.617678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.672378E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.727878E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.787578E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.852678E 03	0.162171E 05	0.342894E 05	0.0	0.0
0.917378E 03	0.162171E 05	0.342894E 05	0.0	0.0

CLOUD TRAJECTORY

XC	YC	ZC	TC	VC
0.517050E 02	-0.331475E 02	0.305655E 04	0.128730E 02	0.175835E 03
0.524578E 02	-0.336304E 02	0.313028E 04	0.130655E 02	0.187400E 03
0.542143E 02	-0.347566E 02	0.321227E 04	0.135030E 02	0.203154E 03
0.577274E 02	-0.370098E 02	0.359066E 04	0.143780E 02	0.230754E 03
0.641359E 02	-0.408173E 02	0.373619E 04	0.158780E 02	0.255102E 03
0.718579E 02	-0.444473E 02	0.412484E 04	0.173779E 02	0.257859E 03
0.865348E 02	-0.474941E 02	0.476549E 04	0.198779E 02	0.237005E 03
0.108399E 03	-0.540272E 02	0.546051E 04	0.228779E 02	0.217390E 03
0.137739E 03	-0.576433E 02	0.624138E 04	0.263779E 02	0.201755E 03
0.179709E 03	-0.601732E 02	0.714327E 04	0.308779E 02	0.190416E 03
0.239791E 03	-0.580115E 02	0.815766E 04	0.363779E 02	0.184573E 03
0.322010E 03	-0.486687E 02	0.925730E 04	0.428779E 02	0.175905E 03
0.440207E 03	-0.280747E 02	[illegible]	0.508779E 02	0.164524E 03
0.582219E 03	-0.639555E 01	0.124291E 05	0.593779E 02	0.165549E 03
0.754960E 03	0.161510E 02	0.143746E 05	0.693779E 02	0.166535E 03
0.915069E 03	0.338241E 02	0.165694E 05	0.808779E 02	0.155593E 03

0.996616E 03	0.456117E 02	0.191893E 05	0.936779E 02	0.180471E 03
0.974697E 03	0.393781E 02	0.218061E 05	0.108373E 03	0.128855E 03
0.844363E 03	-0.517726E 01	0.243189E 05	0.127873E 03	0.574165E 02
0.641203E 03	-0.500902E 02	0.251601E 05	0.142873E 03	0.365820E 01
0.360123E 03	-0.110830E 03	0.252533E 05	0.162373E 03	0.0
0.877319E 01	-0.186755E 03	0.252533E 05	0.187373E 03	0.0
-0.272307E 03	-0.247493E 03	0.252533E 05	0.207873E 03	0.0
-0.623656E 03	-0.323420E 03	0.252533E 05	0.232378E 03	0.0
-0.104528E 04	-0.414530E 03	0.252533E 05	0.262878E 03	0.0
-0.146690E 04	-0.505440E 03	0.252533E 05	0.292378E 03	0.0
-0.198852E 04	-0.596750E 03	0.252533E 05	0.322373E 03	0.0
-0.238041E 04	-0.703044E 03	0.252533E 05	0.357873E 03	0.0
-0.287230E 04	-0.809339E 03	0.252533E 05	0.392373E 03	0.0
-0.343446E 04	-0.930215E 03	0.252533E 05	0.432873E 03	0.0
-0.406689E 04	-0.104674E 04	0.252533E 05	0.477573E 03	0.0
-0.465931E 04	-0.120461E 04	0.252533E 05	0.522378E 03	0.0
-0.533174E 04	-0.134091E 04	0.252533E 05	0.557875E 03	0.0
-0.6[illegible]E 04	-0.149261E 04	0.252533E 05	0.617373E 03	0.0
-0.6[illegible]E 04	-0.165[illegible]E 04	0.252533E 05	0.672373E 03	0.0
-0.7[illegible]038E 04	-0.18[illegible]E 04	0.252533E 05	0.727373E 03	0.0
-0.8[illegible]362E 04	-0.200[illegible]E 04	0.252533E 05	0.787373E 03	0.0
-0.933713E 04	-0.220[illegible]E 04	0.252533E 05	0.852875E 03	0.0
-0.11[illegible]506E 05	-0.240[illegible]E 04	0.252533E 05	0.917373E 03	0.0

BLOCK COUNT = 07

PARTICLE BLOCK BEFORE SHIFT

X	Y	T	PSIZ	PMAS	Z	[illegible]	[illegible]	[illegible]	VNAF
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.33473E 04	0.53016E 03	0.62730E 04	0.18294E 11
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.42614E 04	0.53016E 03	0.54010E 04	0.25928E 11
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.54751E 04	0.53016E 03	0.54312E 04	0.48952E 11
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.70043E 04	0.53016E 03	0.63614E 04	0.69100E 11
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.89533E 04	0.53016E 03	0.73915E 04	0.13104E 12
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.11453E 05	0.53016E 03	0.79217E 04	0.21438E 12
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.14653E 05	0.53016E 03	0.84513E 04	0.35072E 12
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.18745E 05	0.53016E 03	0.89820E 04	0.57376E 12
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.[illegible]E 04	0.23977E 05	0.53016E 03	0.95122E 04	0.93467E 12
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.21847E 07	0.10340E 05	0.30653E 05	0.53016E 03	0.10042E 05	0.15356E 13
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.10923E 08	0.91236E 04	0.31430E 05	0.26039E 04	0.75150E 04	0.74557E 13
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.10923E 08	0.11726E 05	0.51200E 05	0.26039E 04	0.10120E 05	0.19490E 14
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.10923E 08	0.11077E 05	0.52334E 05	0.31386E 04	0.92381E 04	0.25947E 14
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.10923E 08	0.14216E 05	0.74362E 05	0.31386E 04	0.12377E 05	0.52386E 14
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.10923E 08	0.13531E 05	0.57257E 05	0.42142E 04	0.11200E 05	0.59011E 14
0.0	0.0	0.917[illegible]E 03	0.80709E-03	0.10923E 08	0.17745E 05	0.83236E 05	0.42142E 04	0.15414E 05	0.90464E 14
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.64034E 04	0.33358E 04	0.40693E 03	0.31729E 04	0.14396E 11
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.68104E 04	0.44440E 04	0.40693E 03	0.35733E 04	0.24659E 11
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.92173E 04	0.53165E 04	0.40693E 03	0.39363E 04	0.42238E 11
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.96242E 04	0.75127E 04	0.40693E 03	0.93337E 04	0.72349E 11
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.10031E 05	0.96633E 04	0.40693E 03	0.93026E 04	0.12393E 12
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.10438E 05	0.13040E 05	0.40693E 03	0.10203E 05	0.21227E 12
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.10845E 05	0.17055E 05	0.40693E 03	0.10615E 05	0.34360E 12
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.11252E 05	0.22335E 05	0.40693E 03	0.11021E 05	0.62280E 12
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.11659E 05	0.29232E 05	0.40693E 03	0.11423E 05	0.10668E 13
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 07	0.12066E 05	0.38253E 05	0.40693E 03	0.11835E 05	0.18273E 13
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.10923E 08	0.11800E 05	0.43571E 05	0.20504E 04	0.10572E 05	0.11598E 14
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.10923E 08	0.13851E 05	0.65330E 05	0.20504E 04	0.12623E 05	0.26123E 14
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 08	0.16214E 05	0.73115E 05	0.58516E 04	0.12724E 05	0.10667E 15
0.0	0.0	0.917[illegible]E 03	0.58219E-03	0.21847E 08	0.19424E 05	0.88851E 05	0.75783E 04	0.15515E 05	0.18774E 15
0.0	0.0	0.917[illegible]E 03	0.48040E-03	0.21847E 07	0.96[illegible]E 04	0.34232E 04	0.35587E 03	0.36050E 04	0.12803E 11

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13. ABSTRACT

The theoretical bases of a land-surface-burst nuclear-cloud-rise model and details of development from the theoretical model of the DELFIC Cloud Rise Module computer program are presented. By use of this dynamic cloud rise model, histories of the rise, growth, temperature, and composition of the cloud are computed throughout virtually the entire period of its rise. Effects on the cloud development of atmospheric structure can be accounted for, and the development of a time-temperature history for the cloud allows fractionation of the radioactive weapon debris to be approximately accounted for in the Particle Activity Module (DASA-1800-V) calculations.

Also described is the DELFIC Cloud Rise-Transport Interface Module (CRTIM). The CRTIM corrects particle positions for wind-drift during the cloud rise time period and prepares the particles aloft imputs for the DELFIC Transport Module (DASA-1800-IV).

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